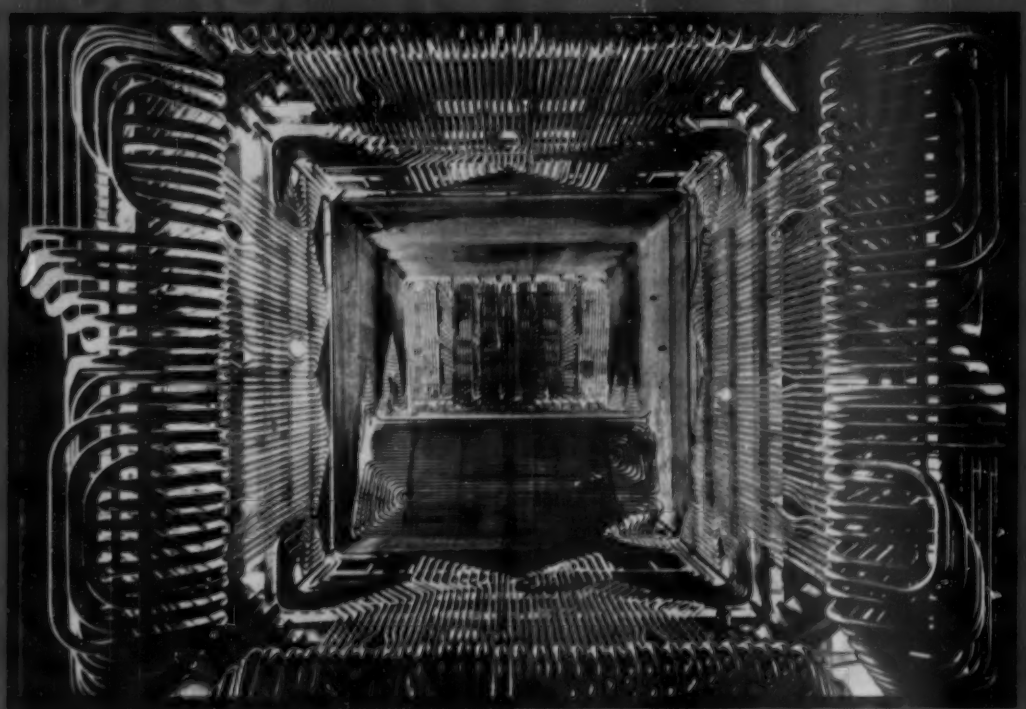
# COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

**April 1955**

Interior view of a 275,000 lbs. per hr, 1450 psig, 980 F Monotube steam generator installed in a European plant

## Vermilion Station Employs Cooling Tower Economies

## Thermodynamic and Physical Properties of Water

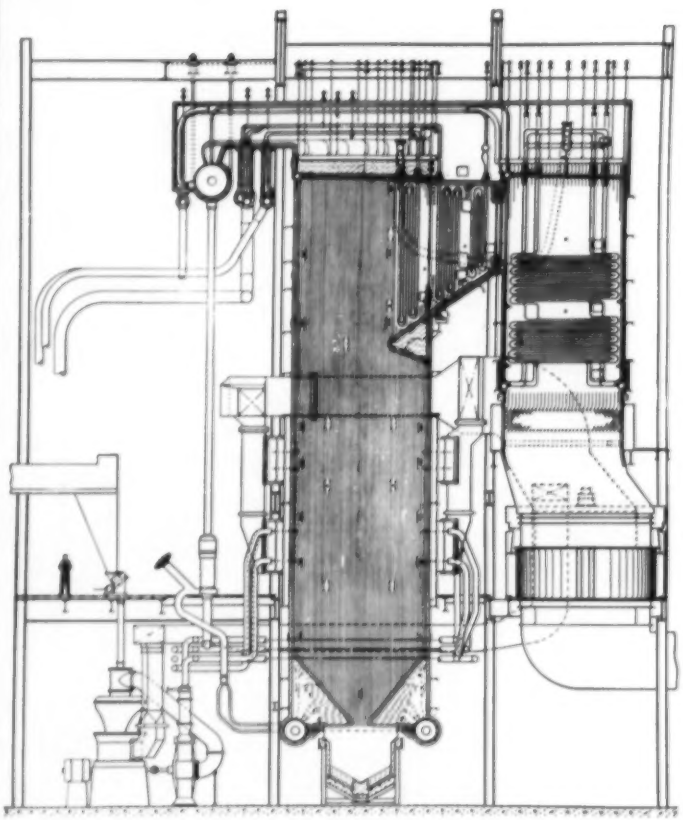
## The Monotube Once-Through Boiler

## American Power Conference Report

# POSSUM POINT STATION

## Virginia Electric & Power Company

# C-E controlled circulation boilers



The C-E Unit shown above is presently under construction in the Possum Point Station of the Virginia Electric & Power Company at Dumfries, Virginia. Stone & Webster Engineering Corporation are the engineers and constructors.

It is designed to serve a 100,000 kw turbine-generator operating at a throttle pressure of 1450 psi with a primary steam temperature of 1000 F, reheated to 1000 F.

The unit is of the controlled-circulation, radiant type with a reheater section located between the primary and secondary superheater surfaces. An economizer section is located below the rear superheater section and regenerative type heaters follow the economizer surface.

Pulverized coal firing is employed, using bowl mills and tilting, tangential burners. Arrangements are made to use oil as an alternate fuel.

B-808

**COMBUSTION ENGINEERING, INC.**

Combustion Engineering Building
200 Madison Avenue, New York 16, N. Y.

BOILERS, FUEL BURNING & RELATED EQUIPMENT; PULVERIZERS, AIR SEPARATORS & FLASH DRYING SYSTEMS; PRESSURE VESSELS; AUTOMATIC WATER HEATERS; SOIL PIPE

# COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

**Vol. 25** **No. 10**

## APRIL 1955

## Feature Articles

Vermilion Station Features Cooling Tower Economies In Station Design ..... *By R. L. Martin, L. Appelt and S. L. Chapin* 42

A Survey of Some of the Thermodynamic and Physical Properties of Water ..... *By E. J. Wellman and W. L. Sibbitt* 51

The Monotube Once Through Boiler for Conventional or Supercritical Pressures ..... *By A. T. Hunter* 57

American Power Conference Report ..... 62

Engineers Joint Council Hold First General Assembly ..... 75

## Editorials

A Look into the Future ..... 41

## Departments

New Catalogs & Bulletins ..... 69

Advertising Index ..... 86

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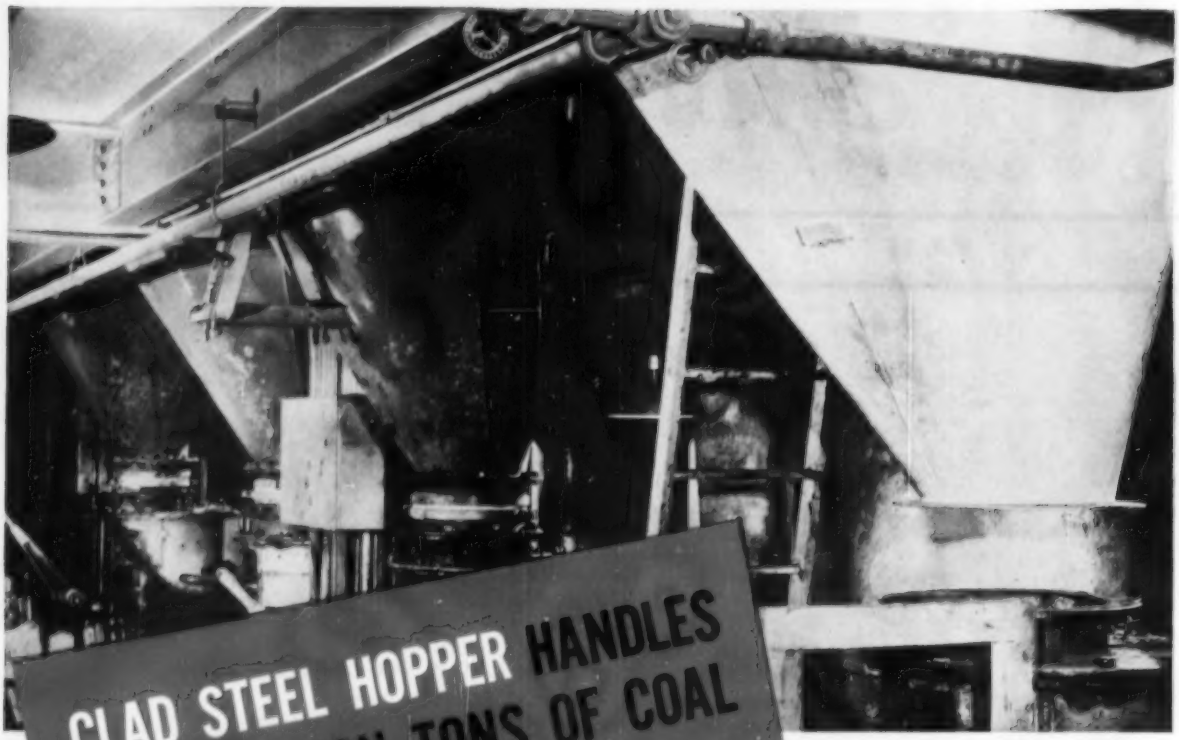


# CLAD STEEL HOPPER HANDLES HALF MILLION TONS OF COAL

*Four stainless-clad steel hoppers at Niagara Mohawk's Huntley Station. The hopper at the extreme right replaces #634, which was recently removed for laboratory analysis.*

After 9½ years of continuous service—handling an estimated 500,000 tons of coal—hopper #634 at Niagara Mohawk's Huntley Station was removed in 1954 for laboratory analysis. It was found to be in perfect condition. This stainless-clad steel hopper had been installed in 1945 to reduce hangups as well as to relieve heavy repair costs. Examination showed no measurable loss of gage, no repairs and a smoother surface than at the time of installation.

Although coal is highly abrasive and when wet inevitably creates sulfuric acid corrosion, this Type 304 stainless-clad steel hopper showed no signs of the abrasive and corrosive effects of coal over the nearly 10-year period. Because of the exceptional performance of stainless-clad steel in this hopper, it has since been specified for other coal handling equipment in the Niagara Mohawk system.

Stainless-clad steel—a layer of solid stainless integrally bonded over its entire surface to a strong, low-cost carbon steel backing—provides all the benefits of solid stainless plate at greater economy. It means long-term savings, too, for clad steel equipment should last the life of the boiler.

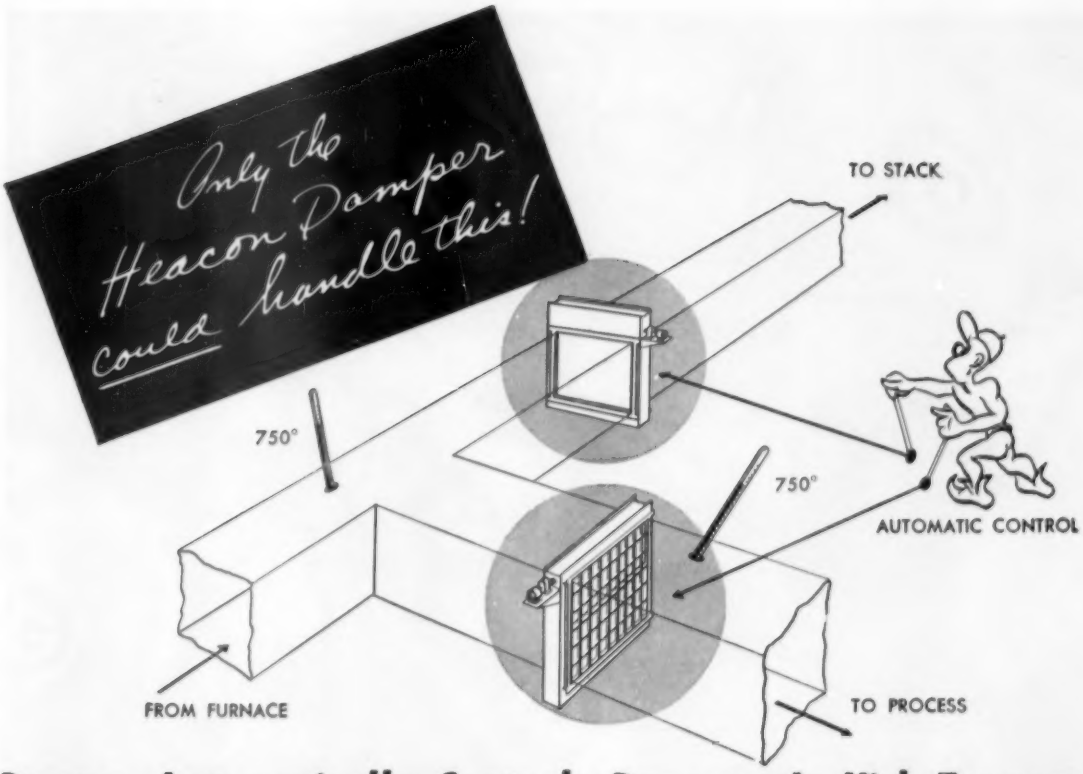
If you would like to find out how clad steel can best serve you, write for Bulletin 740. Lukens Technical Service engineers can provide direct assistance to your builders or your own engineers in the selection and fabrication of the best in coal handling equipment. For the name of a qualified equipment builder, write to Manager, Marketing Service, 684 Lukens Building, Lukens Steel Company, Coatesville, Pennsylvania.


LUKENS

STAINLESS-CLAD STEELS

FOR INTERIOR COAL HANDLING EQUIPMENT

PRODUCER OF THE WIDEST RANGE OF TYPES AND SIZES OF CLAD STEELS AVAILABLE ANYWHERE




# Damper *Automatically* Controls Dangerously High Temperatures

# . . . Safeguards Expensive Processing From Contamination

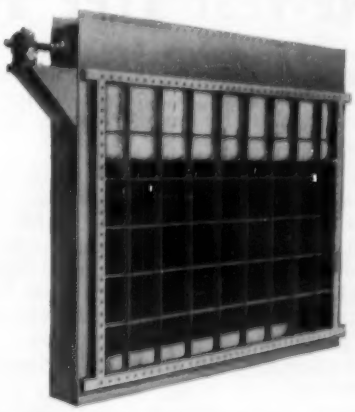
In this installation the safety and success of a new process depends on two factors:
1. Automatic control of high temperatures.
2. Assurance of safety when temperatures approach danger zone.

The process would be impossible without instantaneous and tight shut-off of heat to process and without automatic and dependable venting of heat to the stack. Damper leakage here could mean the loss of thousands of dollars in processing time and materials—not to mention the possible destruction of the plant and its personnel!

Temperatures and pressures had to be under quick, fool-proof control. That's why Heacon Dampers were specified. *Heacon is the only damper made that can assure the positive tightness and control so necessary in this installation!*

The Heacon Damper is a radical departure from conventional damper design. There are no louvers to leak . . . no possibility of warpage. The greater the pressure the more tightly it seals!

Heacon Dampers are designed and constructed to meet practically any pressure or temperature specifications. Our engineers will be glad to discuss your problems with you.



*Project Engineers*

**THE THERMIX CORPORATION**

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**CON EDISON SELECTS...**

*The control gage board for Astoria's No. 10 boiler. At top: Hays Model WSF for mounting above eye level. Right center: Hays Model WCF8P for eye level. Four mounting styles are available to meet special requirements.*

# NEWEST TYPE **Hays Draft Gage**

Consolidated Edison's new Astoria Electric Generating plant at Queens, N.Y. is equipped specifically for the purpose of producing electricity at the lowest cost per kilowatt, reliably and continuously.

To meet these exacting requirements, Con Edison selected Hays W Gage . . . a completely new design in draft gages. Like other Hays low pressure instruments, the draft gage operating mechanism consists of a diaphragm enclosed in a cast metal housing. For pneumatically transmitted readings of Air, Steam, or Water Flow, Pressures, Temperatures, Levels, Oxygen, etc., the operating mechanism employs a bellows. The outstanding new features include: 3-way atmospheric vent cock, easy zero check, removable units for simple adjustment, and Lucite scales for easy reading.

Functionally designed and beautifully styled, the Hays W Gage provides exactly what instrument men have long demanded—an easily adjusted, easy-to-read, dependable draft gage!

*Write today for full information on the Hays W Gage. Publication 52-1060-210.*

Automatic Combustion Control
Boiler Panels • $CO_2$ Recorders
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Gas Analyzers • Draft Gages
Combustion Test Sets
Electronic Oxygen Recorders
Electronic Flowmeters
Electronic Feed Water Controls
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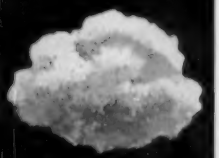
MICHIGAN CITY 1, INDIANA

# Let this be your eyes...

. . . where it's too hot



. . . behind dangerous barriers

. . . inaccessible locations

# where you can't get close!

In more and more steel plants, power stations, and other industries, RCA Closed-Circuit Television is performing jobs that save thousands of dollars annually by preventing injury to personnel, lost time, or damage to products.

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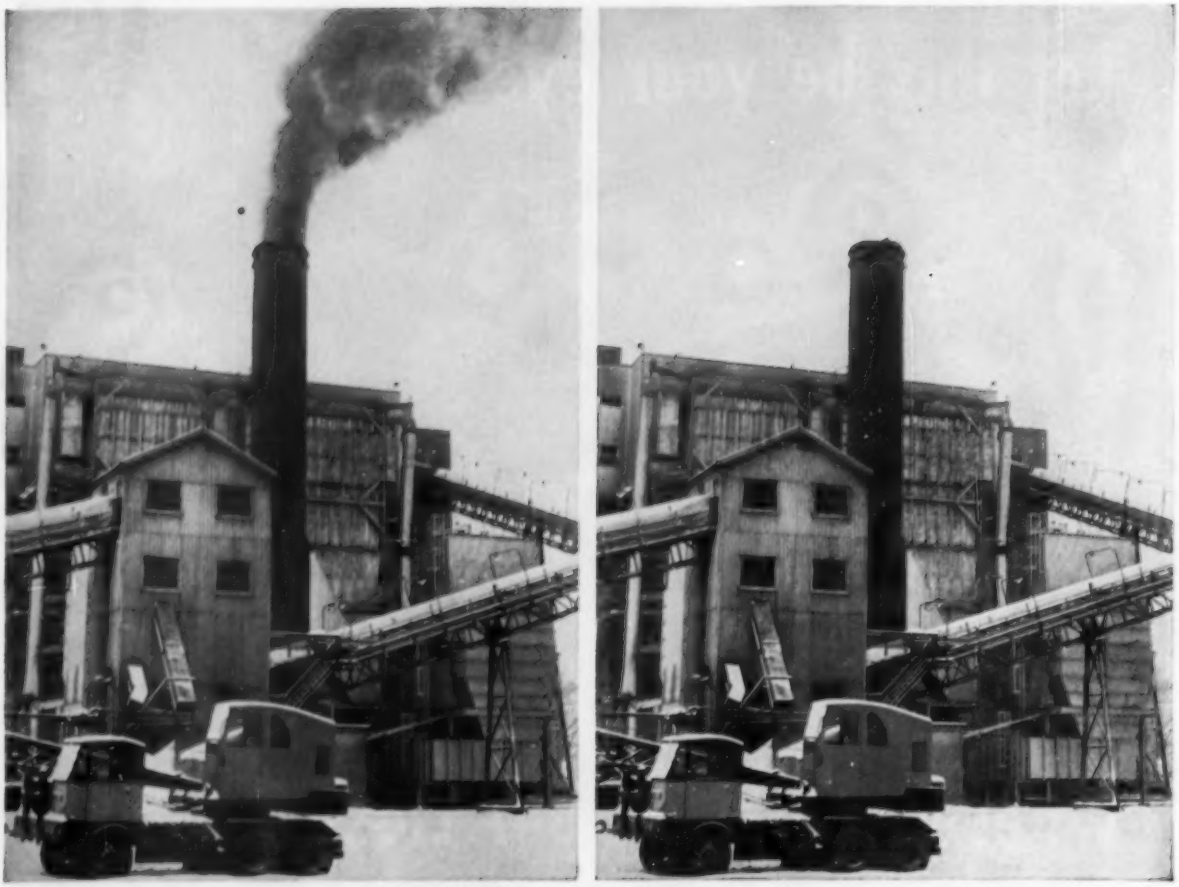

# Fly Ash Problem Solved By Central Station

This Pennsylvania utility felt that as long as you can *see* dirty stack discharge, you have a problem. To solve it, they decided to insist on fly ash collection equipment with very high efficiency.

The electrical precipitators they chose, which were placed after existing mechanical collectors, are Cottrells, designed and built by Research-Cottrell. Their effectiveness is demonstrated in the above unretouched photographs. At the left, the precipitators were turned off long enough to take the picture showing the volume of fly ash discharged by the boilers. At the right, the precipitators are turned back on. Stack discharge is visually clean.

This is another example of industry's trend toward establishing its own higher standards for nuisance abatement. Research-Cottrell, which has made more fly ash installations than any other company, cites the following comparison:

In the period from 1923 to 1939 only 11% of its power plant customers specified fly ash collection efficiency of 95 to 98%. In recent years, that 11% has risen to fully 90%.

One reason, of course, is the generally increasing emphasis on community relations. Another factor is that far-sighted companies are anticipating stricter smoke regulations. They are anxious to install equipment that will end their smoke problems now and also prevent such problems from occurring in the future.

Still another factor is this. In recent years, with modern coal pulverization and advanced boiler design, there has been an increase in the fineness of fly ash particles. This calls for the most efficient equipment available.

Read—in Bulletins FA and MI—about Cottrell equipment and the Research-Cottrell's MI Rapper. This device eliminates rapping puffs and enables the precipitator to maintain, continuously, its high collection efficiency. Write for your copies today.

RC-193

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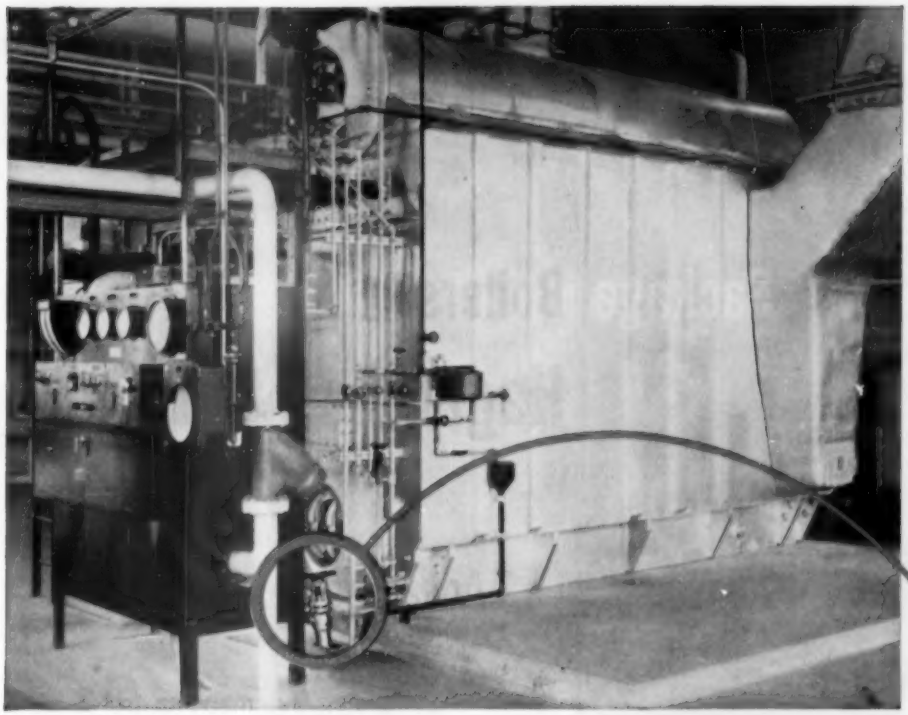


# COMBUSTION ENGINEERING ADOPTS YARWAY SEATLESS BLOW-OFF VALVES FOR PACKAGE BOILERS

Combustion Engineering, Inc. on this package boiler installation at the Orangeburg Pipe Plant in California, again includes Yarway Seatless Blow-Off Valves as part of the "package."

It's a popular idea—and growing fast. All *good* package-type boiler installations are *better* when equipped with Yarway Seatless Blow-Off Valves.

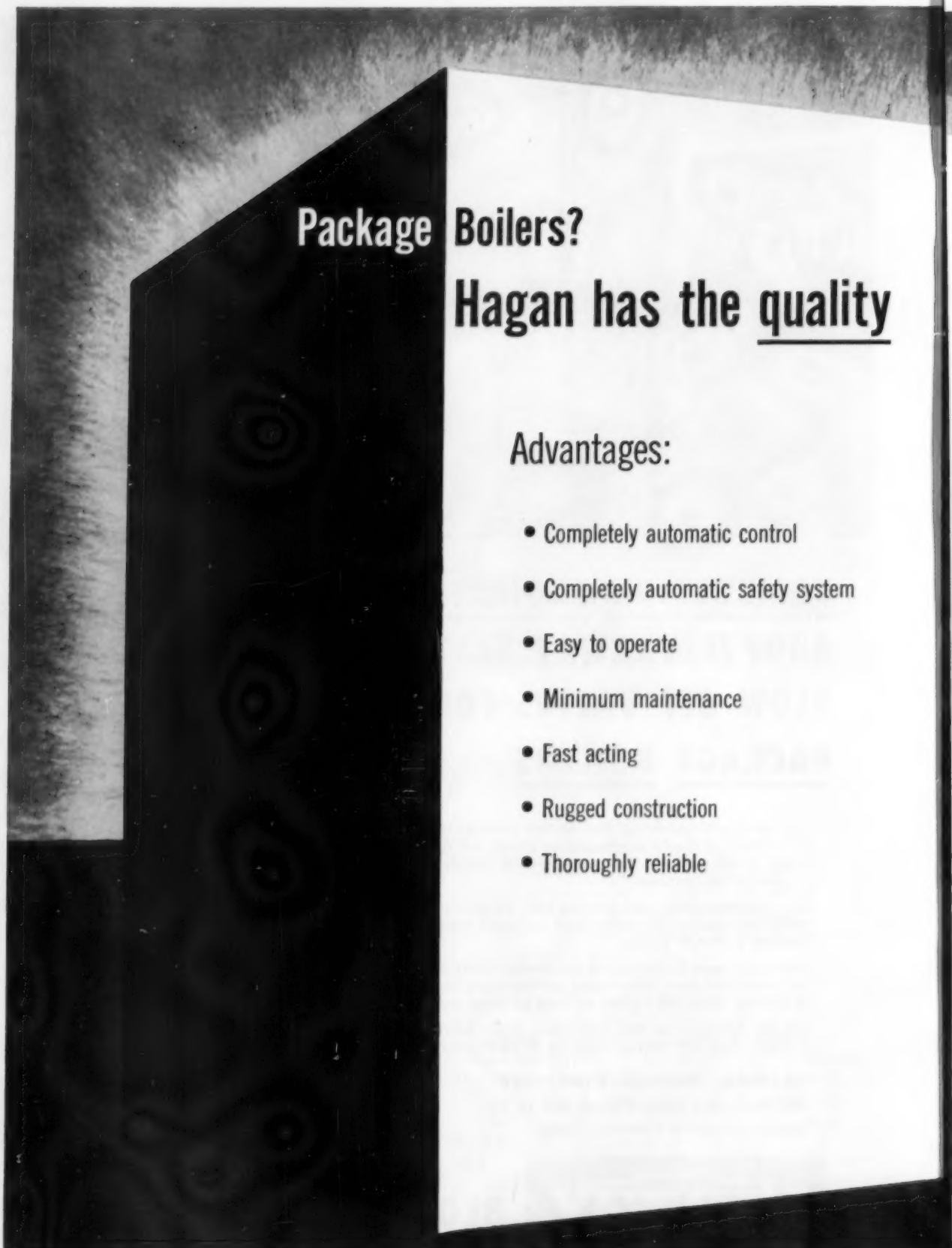
More and more boilermakers are standardizing on Yarways, and more and more boiler users are expecting the advantages of Yarway Blow-Off Valves on their package units.

Get the full story on why more than 15,000 boiler plants use Yarway Blow-Off Valves, some for 30 to 40 years.

**YARNALL-WARING COMPANY**
100 Mermaid Avenue, Philadelphia 18, Pa.
BRANCH OFFICES IN PRINCIPAL CITIES

Yarway Type "B" Seatless Tandem Blow-Off Valve. Note balanced sliding plunger design with no seat to score, wear, clog or leak. Pressures to 400 psi.

YARWAY BLOW-OFF VALVES


Package Boilers?
Hagan has the quality
Advantages:
• Completely automatic control
• Completely automatic safety system
• Easy to operate
• Minimum maintenance
• Fast acting
• Rugged construction
• Thoroughly reliable

# package control to fit your boiler!

Hagan offers a quality control system for your packaged boiler. The Hagan pneumatic Combustion Control System is combined with an automatic and programmed ignition system, both containing adequate safety interlocks. The whole is integrated into a factory pre-assembled and tested control center. Hagan pneumatic systems are easy to operate, will last as long as the boiler, and give you complete control and records.

Each of the six Hagan Control Packages is engineered to meet "big boiler" standards, both in respect to accuracy of control, and to dependability. All of the systems are . . .

## SAFE

The safety system is complete, and so integrated with combustion control that the boiler *cannot* be operated, or if in operation, will *automatically* shut down and set off alarms, if a dangerous condition exists with respect to excessive steam pressure, low water level, low oil pressure or temperature, low gas pressure, low wind box pressure or any electric failure.

## AUTOMATIC

Both combustion control system and the safety system are entirely automatic . . . here is practical "pushbutton" operation. The system is rugged and extremely simple to operate and adjust. Specialized personnel or test and maintenance equipment is not needed. A Hagan system is fast, and will function efficiently with minimum attention and minimum maintenance.

## EFFICIENT

Hagan Automatic Combustion Control provides the most favorable fuel burning efficiency. Since annual fuel costs can easily exceed the total cost of boiler and controls, the gain in efficiency with Hagan control will insure maximum return on the investment in a really complete control system. Hagan Systems are designed to produce high combustion efficiency.

*● Write for Hagan Bulletin No. MSA 128 for the full story on Package Boilers and Hagan Package Control Systems.*

**Specify Hagan Quality Control for Your Package Boiler!**

HAGAN HALL BUROMIN CALGON

# HAGAN CORPORATION

**Hagan Building • Pittsburgh 30, Pennsylvania**

Boiler Combustion Control Systems • Ring Balance Flow and Pressure Instruments • Metallurgical Furnace Control Systems Control Systems for Aeronautical and Automotive Testing Facilities

. . . One leading public utility has a 4,500 psi, 1,150F double reheat cycle unit under construction. Another announced plans for a new supercritical pressure, steam electric station. The single-boiler-turbine-generator unit for this new station will operate at a higher steam temperature and pressure, and will have a capability greater than any installation thus far announced. Using supercritical pressure, and employing two stages of reheat, the new unit should be the most efficient plant thus far projected by the central station industry. The 6,000 psi steam generator will supply steam to the turbine at 5,000 psi, 1,200F. . . .

AS POWER PIPING BECOMES MORE CRITICAL

# M. W. KELLOGG TESTING TECHNIQUES KEEP PACE

To meet the demand for more electric power, and to increase output with the least possible increase in fuel, the trend in utility steam power plants, as reported everywhere, is to higher temperatures and pressures. Thus steam piping—main and reheat—becomes even more critical than before.

One way in which The M. W. Kellogg Company, leading fabricator of power piping, keeps pace with increases in temperature, pressure, and capacity demands is in its testing techniques. Most recent Kellogg development is the company's "atomic camera". Activated by isotopes such as cobalt, iridium, and cesium, this powerful and portable device can photograph welded seams up to six inches thick in a single, short exposure. The same test by traditional X-ray equipment would take considerably longer.

The M. W. Kellogg Company was among the first to be permitted by the AEC to use isotopes of this magnitude. The atomic camera has already proved its value in the construction of many important public utility jobs. It is indicative of the Kellogg research and engineering which guard the vital link between steam power plant boilers and turbines.

M. W. KELLOGG'S "ATOMIC CAMERA"

**FABRICATED PRODUCTS DIVISION**
**THE M. W. KELLOGG COMPANY, 225 BROADWAY, NEW YORK 7, N.Y.**
*The Canadian Kellogg Company, Ltd., Toronto · Kellogg International Corp., London*
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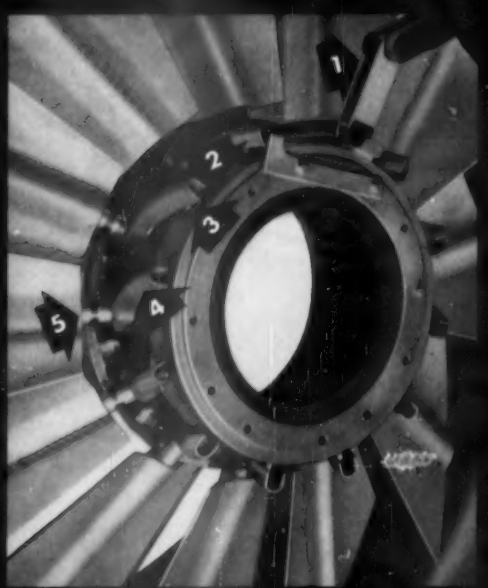
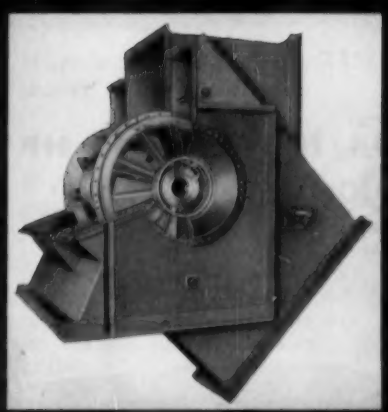
**POWER PIPING—THE VITAL LINK**

# Fact:

## STURDY WESTINGHOUSE-STURTEVANT INLET SPIN CONTROL SAVES FAN POWER WITH CONSTANT-SPEED MOTORS



Operating mechanism is shielded from the gas stream but is readily accessible from the outside for inspection and maintenance.

5-POINT POSITIVE OPERATION. As link and lever (1) moves the operating ring (2) hardened steel spherical pins (3) turn crank arms (4) welded to the tubular vane cores (5). Each vane turns on a heavy steel rod anchored between the center mechanism and outer steel support. No lubrication is required.

### SPIN CONTROL CUTS OPERATING COST

The combination of Westinghouse Inlet Spin Control and the simple squirrel cage constant speed motor is less costly to install and provides greater overall power savings than other types of mechanical draft control.

### SMOOTH, SIMPLE ACTION

Inlet Spin Control has no gears—no backlash. Provides instantaneous control of draft. Vanes move rapidly in the open range, yet fine adjustment is possible in the near-closed position. Extremes of heat and cold do not affect its operation in any way.

### MOST EFFICIENT, MOST ECONOMICAL

In any comparison of both forced and induced draft fans and their control devices, you will find Inlet Spin Control is both the most efficient and economical choice.

### MORE FACTS?

Call your nearest Westinghouse-Sturtevant Sales Engineer . . . he's the "Man with the Facts". . . or fill in the coupon below.

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YOU CAN BE SURE...IF IT'S Westinghouse

J-80441

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*Please send more facts on Inlet Spin Control.*

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ALLIS-CHALMERS

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204 NET ENGINE HP
44,000 LB

Nowhere can you match the HD-21
in the amount of work it will do!

**. . . for more power—better performance—longer life . . .**

# BIGGEST, MOST PRODUCTION ANYWHERE!

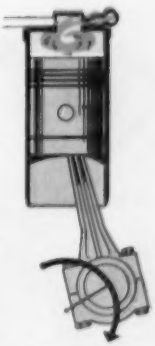
**New standards of output** The HD-21 introduces the new Allis-Chalmers engine and a great new power team. Together, they provide extra speed with any load, extra pulling power at any speed . . . wider speed ranges and more range overlap. And with its advanced design torque converter (*the result of 15 years of leadership by Allis-Chalmers*) the HD-21 puts its power to work with less shifting than ever before possible . . . to help you reach a new high in efficient, profitable production!

**New standards of durability** From the new Allis-Chalmers diesel with "follow-through" combustion to new, heavier Tru-Dimension track, the HD-21 is built to take today's big loads in stride, and come back for more. Here are just a few more of the long-life features you can't get from anyone but Allis-Chalmers . . . at any price: all-steel Box-A main frame, straddle-mounted final drive gears, 1,000-hour truck wheel lubrication, oil-enclosed track release mechanism.

**New low cost per unit of work** The HD-21 offers 20 percent greater over-all performance . . . provides a new measure of tractor value. Add the *planned* approach to service offered by Allis-Chalmers dealers, and it's the ideal team for men tackling today's *big* jobs.

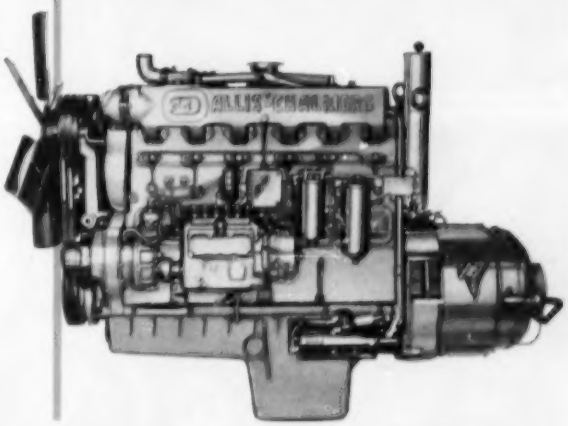
**Here's one of the HD-21's many new features—**

**New Allis-Chalmers engine**



Brings you top performance, extra-long life through a new kind of "*follow-through*" combustion. Here's why—

The key explosion occurs in the energy cell as shown, unleashing a blast that sets up cyclone turbulence. Result—no damaging peak pressures . . . instead, higher average working pressures and better leverage on the crankshaft. *Be sure to ask your Allis-Chalmers dealer for the visual story revealing the full advantages of this new engine.*

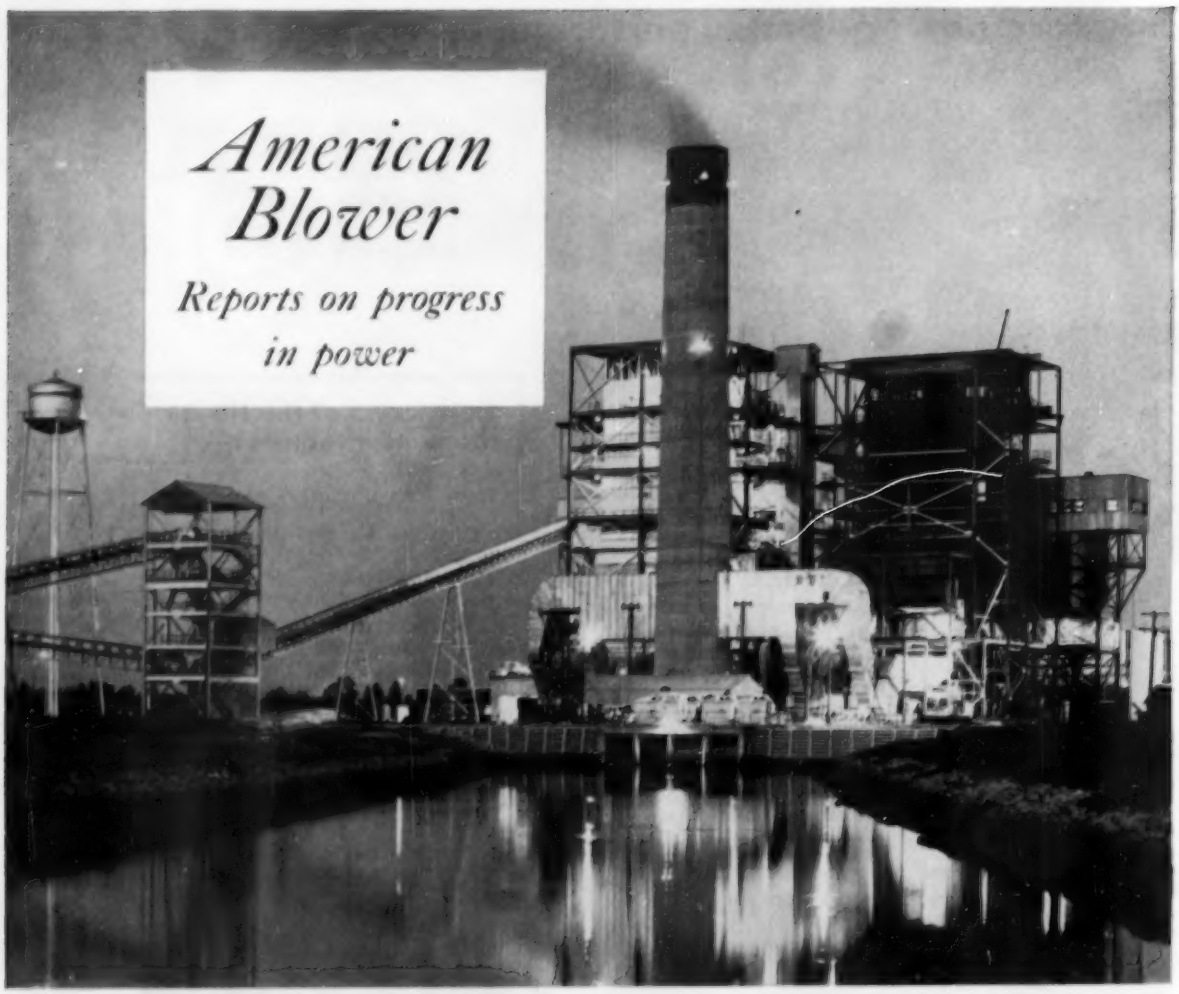


**ALLIS-CHALMERS**

TRACTOR DIVISION • MILWAUKEE 1, U. S. A.

# *American Blower*

*Reports on progress in power*



CP&L's new plant at Wilmington, N.C., has been named the *Louis V. Sutton Steam Electric Generating Plant* in honor of the company's president. The first mammoth boiler of this outdoor-type unit towers 17 stories high, and produces steam up to 1,000° F with 1,600 lbs. pressure per sq. in. CP&L's system includes three other large fuel-burning plants, plus three large hydroelectric plants.

For new #1 unit of Louis V. Sutton Plant, CP&L installed these two American Blower Sirocco/Induced Draft Fans. Each is rated @ 225,000 cfm @ 585 rpm @ 291° F @ 16" sp. If *your* plans call for mechanical draft equipment, fly ash precipitators, heavy-duty steam coils, or fluid drives for boiler feed pump and fan control — contact your American Blower Branch Office, today.

*Serving home and industry:* **AMERICAN-STANDARD • AMERICAN BLOWER • CHURCH SEATS &**

# Carolina Power & Light Co. ups capability to 922,000 kw with new outdoor unit

**Carolina Power & Light Company's new steam plant reflects design progress, uses American Blower Draft Fans**

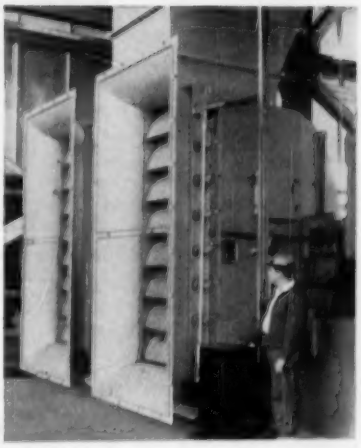
The new Louis V. Sutton Steam Electric Generating Plant at Wilmington, N.C., is the Carolina Power & Light Company's first plant of outdoor-type construction to be built entirely above ground. No. 1 unit, which went into operation July 1954, adds 105,000 kw to CP&L's generating network, boosting total capability to 922,000 kw!

Laid out for a maximum of six generating units, this new plant will be the largest in the company's vast system . . . a system that serves over 2,000,000 people in 30,000 square miles of the Carolinas. Its outdoor design saves on construction costs and time, and reflects CP&L's many years of progress: continually expanding and increasing service to customers.

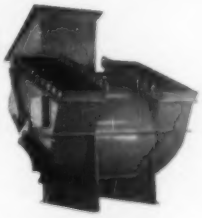
Along with cost-cutting outdoor construction, CP&L chose efficient and dependable equipment, including American Blower Forced and Induced Draft Fans.

Across our nation, progressive, investor-owned utilities prefer American Blower equipment because it performs at peak efficiency, indoors or out, with minimum maintenance. They know you can rely on American Blower's Forced and Induced Draft Fans, Fly Ash Collectors, Gyrol Fluid Drives for boiler feed pump and fan control, and Heavy-duty Steam Coils.

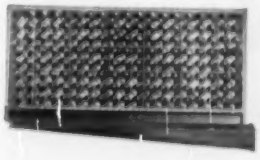
May we assist in *your* progressive program? Give your nearest American Blower Branch Office a call, or write us direct.



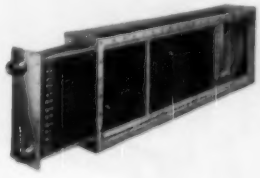
This is one of two American Blower Sirocco Forced Draft Fans installed on #1 unit at CP&L's Louis V. Sutton plant. It is rated @ 140,000 cfm @ 585 rpm @ 100° F @ 14.4" sp.



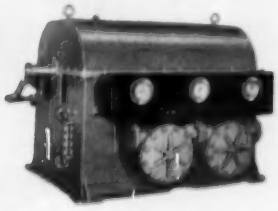
Mechanical Draft Fans for induced and forced draft



Collectors and precipitators for dust and fly ash control



Heavy-duty steam coils for high pressure duty



Gyrol Fluid Drives for boiler feed pump and fan control

AMERICAN BLOWER CORPORATION, DETROIT 32, MICHIGAN • CANADIAN SIROCCO COMPANY, LTD., WINDSOR, ONTARIO

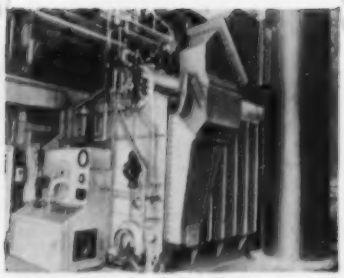
Division of American Radiator & Standard Sanitary Corporation

**AMERICAN BLOWER**

WALL TILE • DETROIT CONTROLS • KEWANEE BOILERS • ROSS EXCHANGERS • SUNBEAM AIR CONDITIONERS

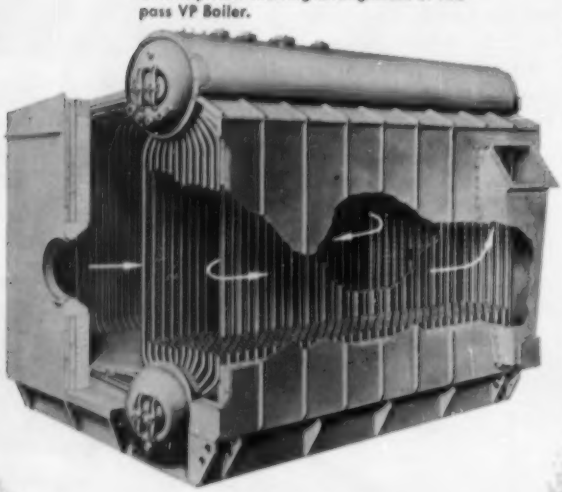
# now...Combustion's VP Boiler with a

# NEW LOOK



Industrial installation of VP Boiler in the South. Capacity — 33,000 lb steam per hr; design pressure 250 psi.

Cutaway view showing arrangement of two-pass VP Boiler.



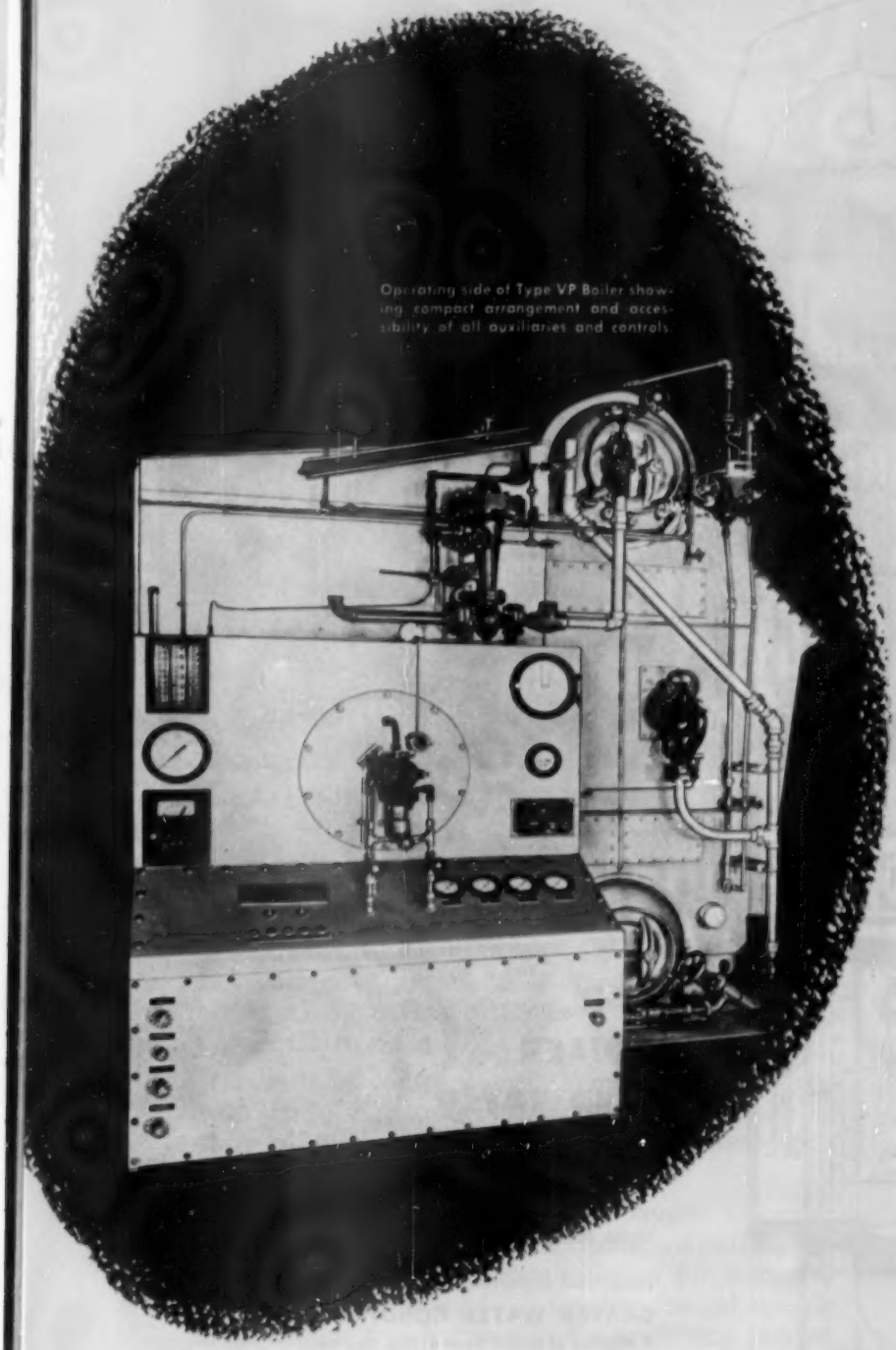
## gives you more steam per dollar!

**COMBUSTION ENGINEERING**

C·E

Combustion Engineering Building • 200 Madison Avenue, New York 16, N. Y.

STEAM GENERATING, FUEL BURNING & RELATED EQUIPMENT; PULVERIZERS, AIR SEPARATORS & FLASH DRYING SYSTEMS; PRESSURE VESSELS; AUTOMATIC WATER HEATERS; SOOT PIPE



Operating side of Type VP Boiler showing compact arrangement and accessibility of all auxiliaries and controls

**Combustion's well known C-E Package Boiler, Type VP, has a *new look*... outside and inside!**

**Outside.** The VP's exterior is more streamlined, more compact. The controls and fan are now an integral part of the boiler front. Duct work is simplified. This means better appearance, easier maintenance, better operation.

**Inside.** Now instead of 2" diameter tubes you'll find 2½" tubes swaged down to 2" at the drums — in all sizes above 15,000 lb per hr capacity. This permits closer spacing of the tube surfaces in the main boiler bank and results in up to 25 per cent more heating surface per tube. It increases mass flow rates, assuring more efficient heat transfer. All this adds to up more steam than from the former VP Boilers of the same size.

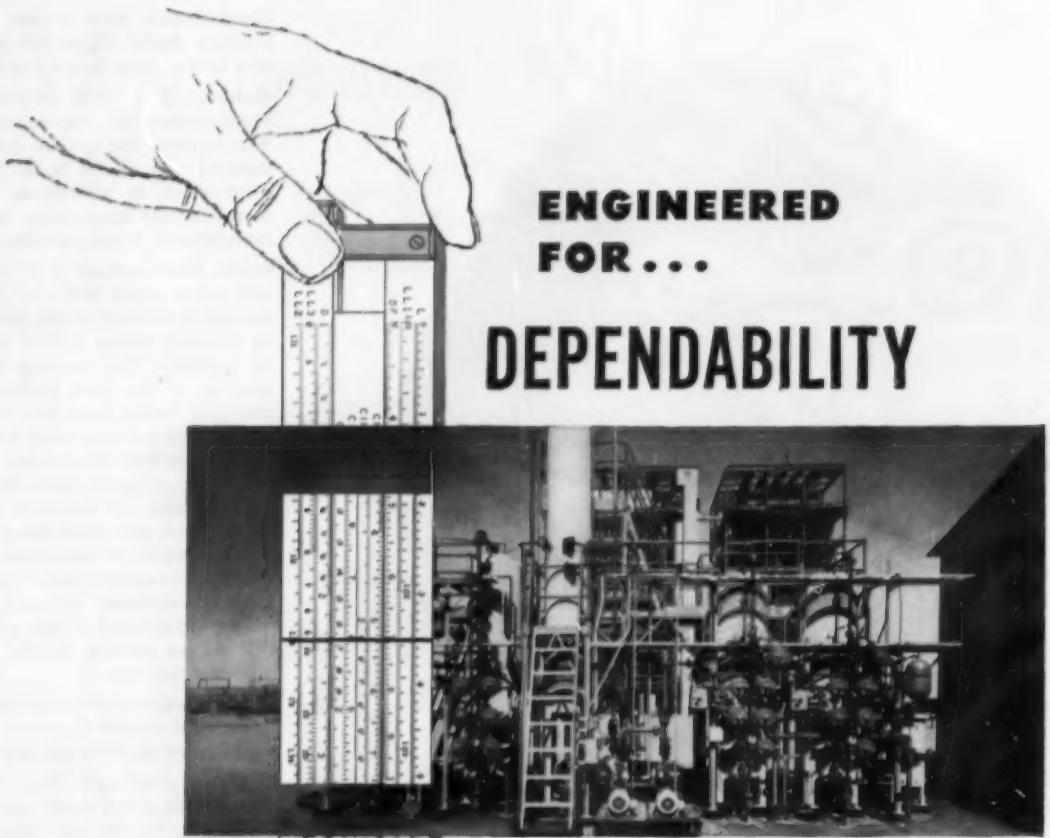
All of the existing *extra* features which contributed to the enthusiastic acceptance of the original VP design remain. Briefly summarized they are:

- **More water cooling** per unit of furnace volume than any other boiler of the VP's size and type.
- ***Quiet centrifugal fan,*** which operates at low speed and with an exceptionally low noise level.
- **Large lower drum,** which facilitates handling wide load swings ... permits a simple, symmetrical tube arrangement ... simplifies inspection.
- **Single Burner** assures balanced furnace conditions and air distribution ... is easier to operate and to maintain ... simple burner control equipment ... no air leakage through idle burner ... change oil gun, when required, in seconds.
- ***Simple baffle arrangement,*** which means maximum heat transfer rate ... no dead gas pockets ... simplified soot blowing.

The *New* VP Boiler not only looks more attractive but it is functionally improved and stands ready to deliver more steam per dollar.

Write, today, for complete information. Ask for new catalog VP-166 (just off the press) which contains specifications and general information on dimensions, space requirements, construction details and controls. B-812

***THE VP BOILER is available in capacities ranging from about 4,000 to 40,000 lbs of steam per hr, and pressures up to 500 psi.***



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DEMINERALIZERS

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TREATMENT

Write for Demineralizer Bulletin WC-111

*Industrial Department: I-111*

GRAVER WATER CONDITIONING CO.

*A Division of Graver Tank & Mfg. Co., Inc.*

216 West 14th Street, New York 11, N. Y.

Prevent heat loss up the stack. Too much or too little excess air means big money in today's boiler plant. It's important to *know* and *control* excess air exactly—regardless of load or fuel changes.

**Burn multiple fuels efficiently**

When switching from one fuel to another or burning more than one fuel at the same time, only an Oxygen Recorder gives you an undistorted picture of excess air. It measures $O_2$ directly and continuously, without recalibration.

Hundreds of companies are reaping large savings with Hays Electronic type Oxygen Recorders in their boiler plants. Flue gas sampling systems fit a wide variety of installations.

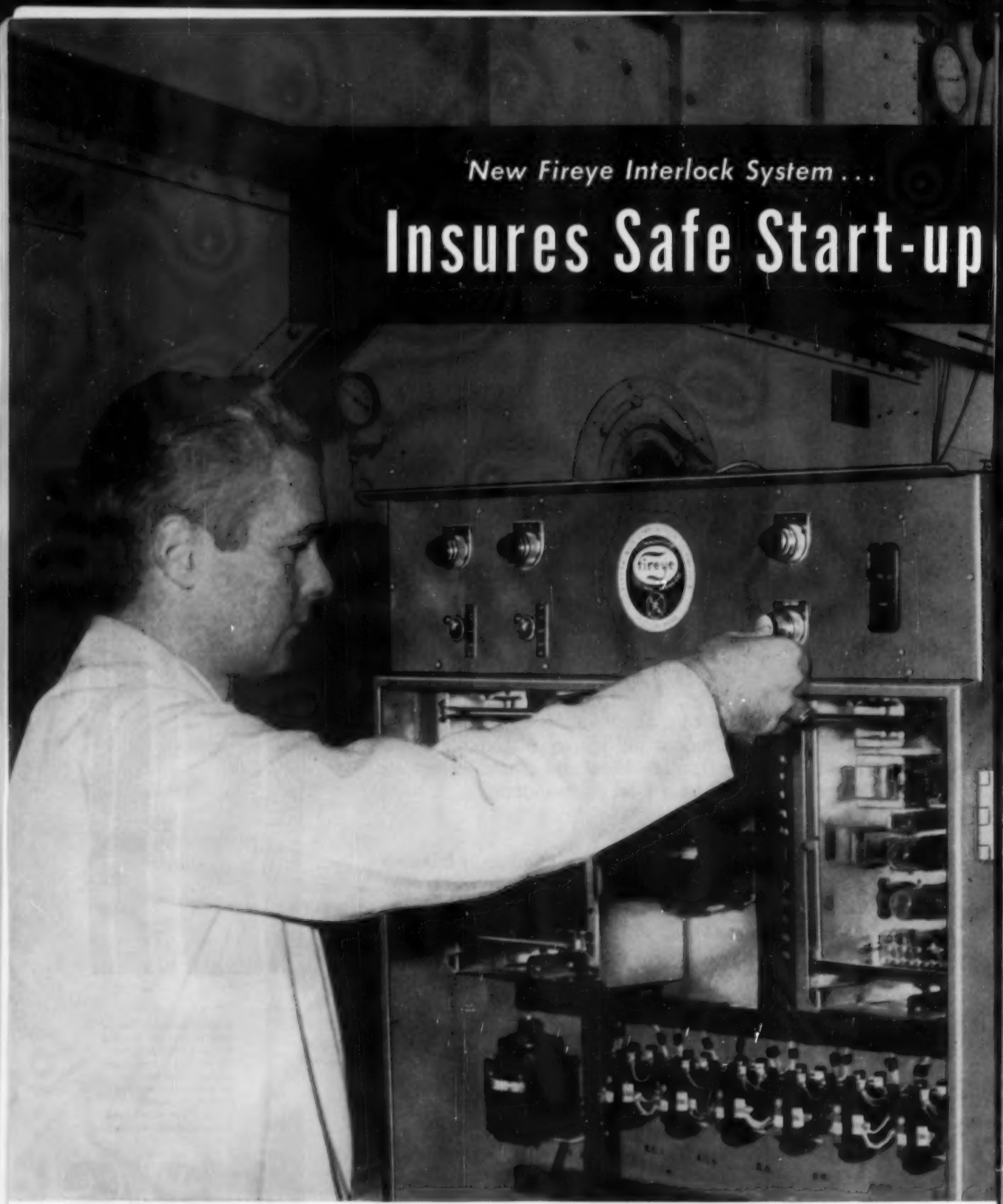
With the Hays Electronic type Oxygen Recorder you get continuous, highly accurate indication and recording . . . complete compensation for temperature and pressure effects . . . freedom from chemicals or hazardous fuel burning in the analyzing process . . . swift, sure electronic operation.

Write today for Hays Bulletin 52-829-56. Also ask for a dramatic comparison graph which shows that the relationship between $O_2$ and excess air is practically constant for different fuels.

Automatic Combustion Control
Boiler Panels • $CO_2$ Recorders
Variflow Meters and Varitrol
Gas Analyzers • Draft Gages
Combustion Test Sets
Electronic Oxygen Recorders
Electronic Flowmeters
Electronic Feed Water Controls
Miniature Remote Indicators

THE **hays** CORPORATION

MICHIGAN CITY 1, INDIANA



*New Fireye Interlock System . . .*

# Insures Safe Start-up

**GET ALL THESE FIREYE ADVANTAGES FOR *YOUR* BOILER OPERATION**

**Purging before ignition • Pilot proving • Time limit on trial-for-ignition**
**Continuous main flame supervision • Instant fuel shutoff and alarm**
**Easy switching to standby fuel • Insurance acceptance • Proved performance**

# and Firing of Power Boilers

Here is the most modern, complete protection your boiler plant can have. Developed by the world's foremost authority on *safe fuel burning*, it is the first fully-integrated combustion safeguard system for hand torch or pilot ignited oil or gas burners. It automatically enforces safe light-off procedure and supervises the flame during firing.

Each step of lighting-off each burner is safety-controlled by Fireye's system of timers, interlocks and shutoff valves. In case of flame failure, the system automatically shuts off the fuel within 2 to 4 seconds, and will not permit re-ignition without complete purging of the combustion chamber.

Be sure *you* have this complete protection: This Fireye development includes a pre-wired and tested cabinet assembly of safeguards and controls for any number of burners . . . and all external valves, switches and alarms. It can be installed on any multiple burner furnace. Installation supervision by a qualified Fireye engineer is avaliable. For full information, send the coupon below.

**COMBUSTION CONTROL DIVISION**
**ELECTRONICS CORPORATION OF AMERICA**
**718 Beacon St., Boston, Mass.**

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E C A fireye

**Electronics Corporation of America, Department C25-4**
**718 Beacon Street, Boston 15, Massachusetts**

Please send me your new bulletin describing safe start-up and firing practices for multiple burner boilers.

NAME _____

COMPANY _____

STREET _____ CITY _____

# "Under Way On Nuclear Power"

As she blinked this terse message, the *USS Nautilus* cast off and steamed to sea leaving an old era of oceanic travel in its wake.

This is the first nuclear-powered, steam-turbine-driven submarine ever to be built. With the eyes of the world watching, it was a project with no margin for failure. Exhaustive sea trials which tested every feature of her equipment proved that the only acceptable result—success—had been completely realized.

We take pride in Walworth's share in this momentous achievement. For, from the days when the *Nautilus* was still on the drawing board to the last stage of construction, Walworth engineers worked directly with the Electric Boat Division of the General Dynamics Corporation—helping with the myriad of piping problems this new concept of transportation posed. Now the *Nautilus* prepares to join the fleet with Walworth Valves and Fittings, both standard and special items, installed.

We are glad to be aboard.

**WALWORTH**

*Manufacturers since 1842*

**valves . . . pipe fittings . . . pipe wrenches**

60 East 42nd Street, New York 17, N. Y.

DISTRIBUTORS IN PRINCIPAL CENTERS
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# *Clear skies for* RICHFIELD PRODUCTS *the Richfield eagle*

**Buell Dust Collection Equipment keeps new $40,000,000 refinery operating under nation's toughest code**

The Los Angeles Refinery* of the Richfield Oil Company needed the "impossible" from a dust recovery system . . . and the problem was put squarely up to Buell. Buell Engineers designed and installed a series of Multi-Stage High Efficiency Cyclone Collectors in tandem with a Buell "SF" Electric Precipitator.

Result: The world's most modern refinery operates within the limits of the Los Angeles Anti-Dust Code . . . recovers tons of re-useable dust daily which results in substantial savings.

This is another example of how Buell Engineers accept full responsibility—from the problem stage to its successful solution . . . why so many of America's Leading Corporations depend upon Buell so completely.

You'll find that our booklet—"The Collection and Recovery of Industrial Dusts"—explains *all three* Buell Dust Collection Systems simply and clearly. Write Dept. 70-D, Buell Engineering Company, 70 Pine Street, New York 5, New York.

**Built by C. F. Braun & Co.*

MECHANICAL ELECTRICAL

buell®

*20 Years of Engineered Efficiency in* **DUST COLLECTION SYSTEMS**

# Dearborn®

**LEADER IN WATER CONDITIONING AND RUST PREVENTION**

DEARBORN CHEMICAL COMPANY • MERCHANDISE MART PLAZA • CHICAGO 54, ILL.

# what's wrong with $H_2O$?

Nothing...except that it's so rarely found in its pure state. Even rain, nature's closest approach to pure water, contains carbon dioxide and dissolved oxygen. So it is, in varying degrees, with every surface or underground water supply. All waters have certain corrosive impurities that must be corrected or neutralized before they can be economically used. There's where we come in.

Since 1887, Dearborn has worked with water to make water work better and more economically for you. That's why, today, industrial and commercial businesses of every size and type look to Dearborn for consultation and assistance in—

- ★ **Internal or external feed water treatment**
- ★ **Steam purity control**
- ★ **Feeding, softening or de-ionizing equipment**
- ★ **Cooling water or process water treatment**
- ★ **Water reclamation**
- ★ **Treating industrial waste**

This broad experience of Dearborn's is available to you. Your Dearborn Water Treatment Engineer will gladly explain the advantages of Dearborn Supervisory Service—a program in which you use only the amount of service you need.

Why not investigate? There's no obligation.

**MAIL THE COUPON!**

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Dearborn Chemical Company
Merchandise Mart Plaza, Chicago 54, Illinois

☐ Please furnish more information on Dearborn Water Conditioning

☐ Have a Dearborn Water Treatment Engineer call

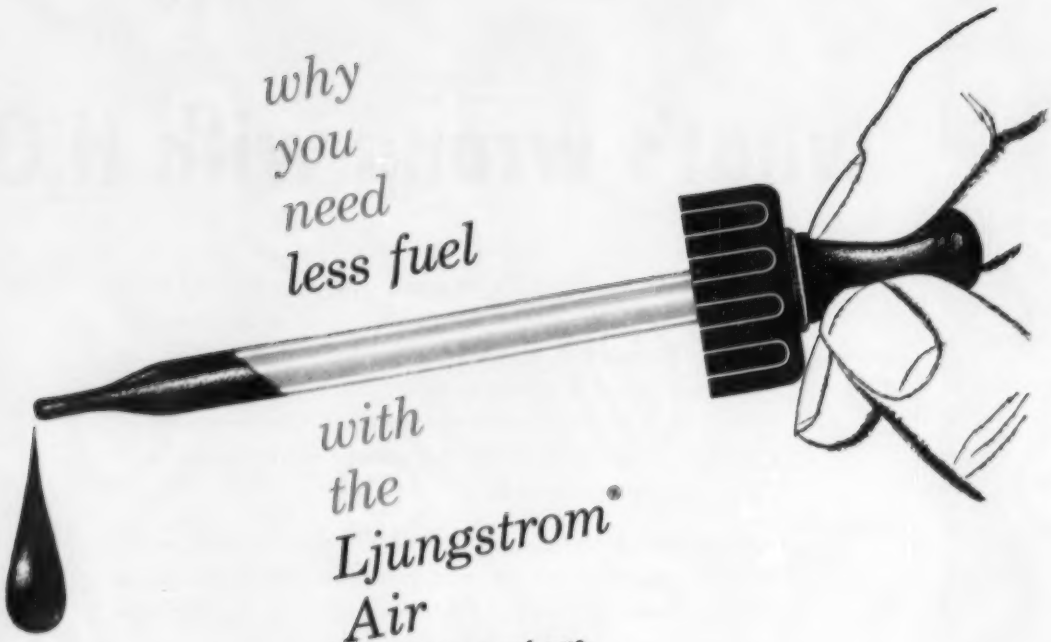
*Name*.....*Title*.....

*Company*.....

*Address*.....

*City*.....*Zone*.....*State*.....

# *why you need less fuel with the Ljungstrom® Air Preheater*

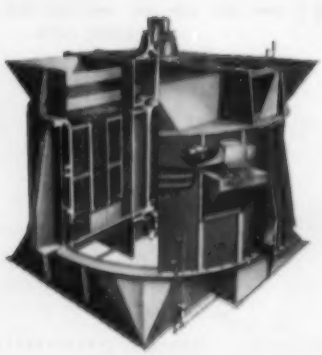


With every 45-50 F of air preheat — you cut your fuel bill 1%. That's why it pays to equip your boilers with Ljungstrom Air Preheaters. For the Ljungstrom is the most efficient air preheater there is.

***Advantages of the Ljungstrom Air Preheater***

- **Size for size, recovers more heat than any other type.**
- **Reduces fuel consumption. Permits use of lower-grade fuels. Increases boiler output and reliability.**
- **Eliminates cold spots . . . keeps corrosion to a minimum.**
- **Easier, faster to clean and maintain.**
- **Requires far less supporting steel and is quickly erected.**

The Ljungstrom also gives industrial plants broad latitude in their choice of fuels. Its unmatched preheating efficiency makes practical and effective such low-grade fuels as saw and paper mill refuse, wood, lignites, peat and bagasse.



Outright fuel economy is reason enough why 7 out of 10 modern preheater installations are Ljungstrom, and why Ljungstrom percentage of installed boiler capacity increases every day. Yet it's just one of the many advantages of the Ljungstrom. Get all the details on why the Ljungstrom cuts fuel costs . . . why it's the most efficient heating surface on the modern boiler . . . why it's easier to clean and maintain. All the details are in the new, 38-page reference manual, "Ljungstrom Air Preheaters." Write for it, today.

**The Air Preheater Corporation** 60 East 42nd Street, New York 17, N. Y.

# New Prudential Building to burn coal the modern way

Ultra-modern in all respects, the new 41-story building of the Prudential Insurance Company of America in Chicago incorporates the latest developments in design, fixtures and construction. This beautiful structure will be completely air-conditioned and will offer its occupants all possible conveniences.

Among those conveniences will be Prudential's heating system, as up-to-date as the building itself. This most modern building in the country will burn *coal*. Cleanly. Efficiently. And its completely automatic coal handling and burning installation will provide sure, even heat *economically* under all conditions.

### Investigate Your Fuel Costs

If you're planning to modernize your plant or build a new one—or if you are just interested in cutting fuel costs—find out how coal, burned the modern way, compares to other fuels. Why not talk to a consulting engineer or your nearest coal distributor. Their advice may save you thousands of dollars each year.

## *facts* you should know about coal

Up-to-date coal burning equipment can give you 10% to 40% more steam per dollar.

Automatic coal and ash handling systems result in a virtually labor-free plant.

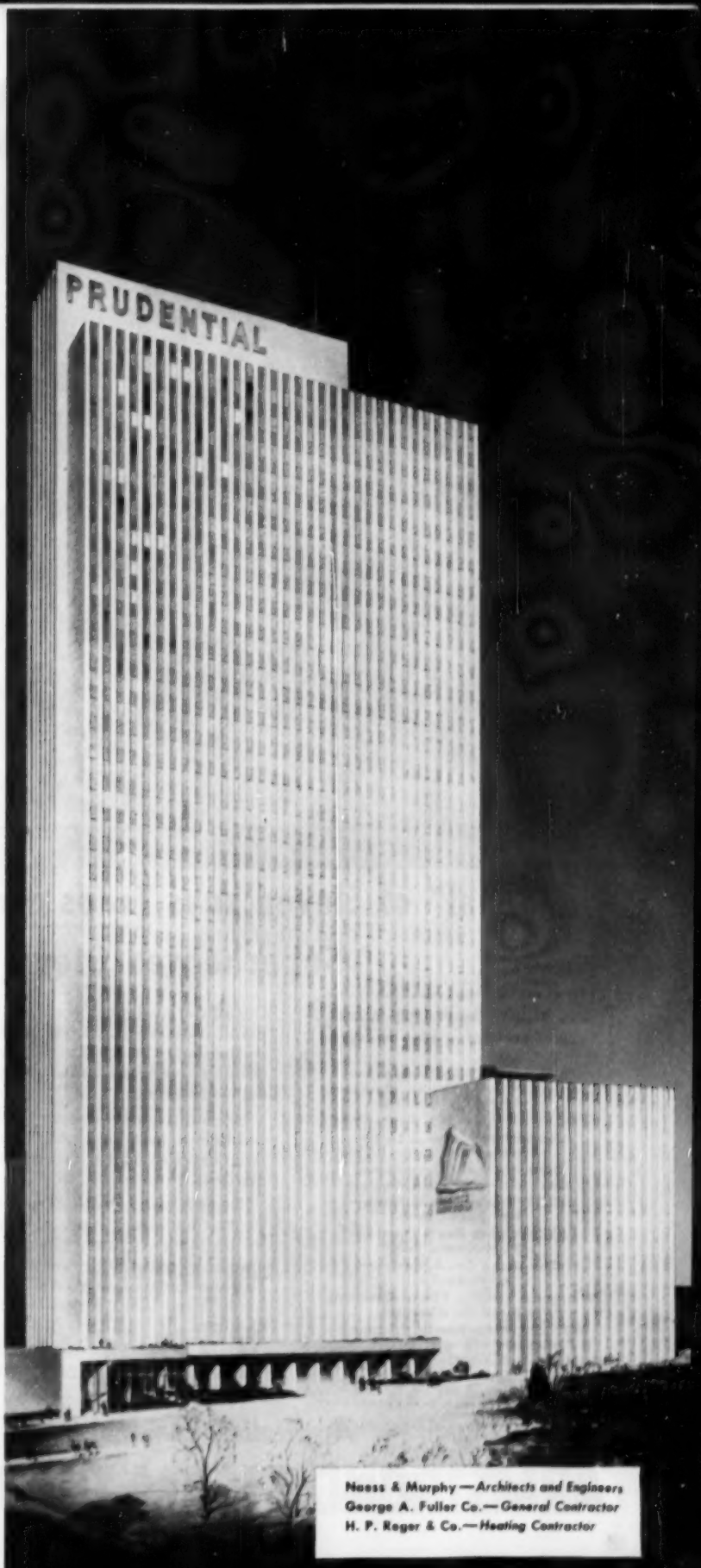
Coal is the safest fuel to store and use. No dust or smoke problems when coal is burned with modern equipment.

In most industrial areas, bituminous coal is the lowest-cost fuel available.

Between America's vast coal reserves and mechanized coal production methods, you can count on coal being plentiful and its price remaining stable.

For further information or additional case histories showing how other plants have saved money burning coal, write to the address below.

NATIONAL COAL ASSOCIATION
Southern Building, Washington 5, D.C.




Naess & Murphy — *Architects and Engineers*
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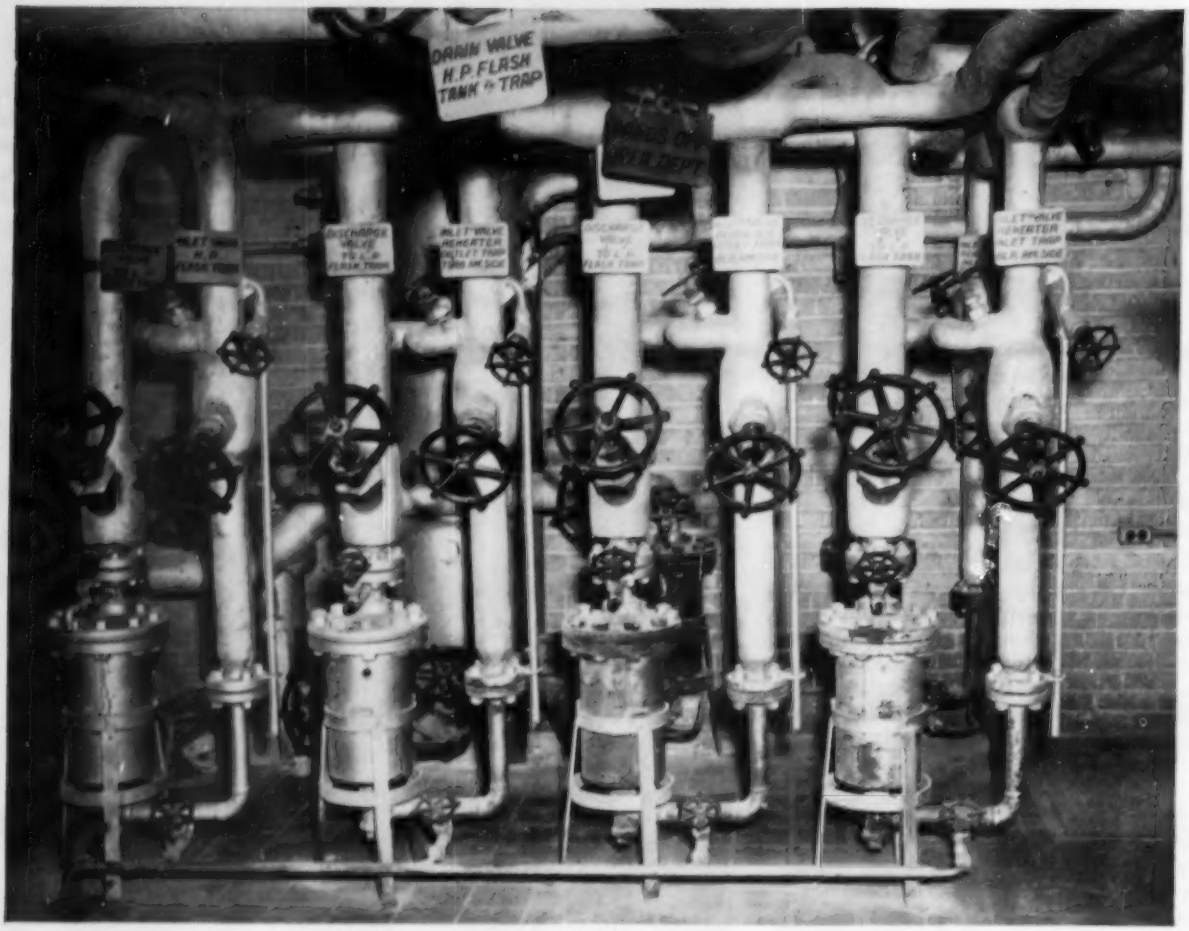



# "Panel" of Eleven says Traps are Best for draining Superheated Steam Lines

**. . . AND THESE PLANTS AGREE**

**Typical Armstrong high pressure trap users:**

**Consumers Power Company—Comstock, Erie, Essexville, Muskegon, Zolwaukee, Michigan**

**Ohio Power Company, Phila, Ohio**

**Kansas City Power & Light—Kansas City, Mo.**

**Georgia Power Company—Yates, Macon, McManus, Georgia**

**United Illuminating Company—New Haven, Conn.**

**Philadelphia Gas & Electric—Philadelphia, Pa.**

**San Diego Gas & Electric—San Diego, Calif.**

**Wisconsin Electric Power Company, Milwaukee, Wisconsin**

**Northern States Power Company—St. Paul, Granite Falls, Black Dog, Minn.**

**Cincinnati Gas & Electric Company, Cincinnati, Ohio**

One of the readers of a power plant publication recently asked, "which is the best device for removing condensate from lines carrying superheated steam . . ."

Eleven readers answerd this published question. *All* agreed, from experience, that steam traps are best.

Traps are automatic. Traps prevent steam loss. Traps take care of boiler carryover. Traps are available with sufficient capacity to take care of any condensate load. Traps don't "forget" to drain the lines.

Since 1929, Armstrong inverted bucket forged steel steam traps have kept pace with the trend to higher steam pressures. Today, they are widely recognized as essential safety devices in leading power plants throughout the world operating at pressures up to 2400 psig.

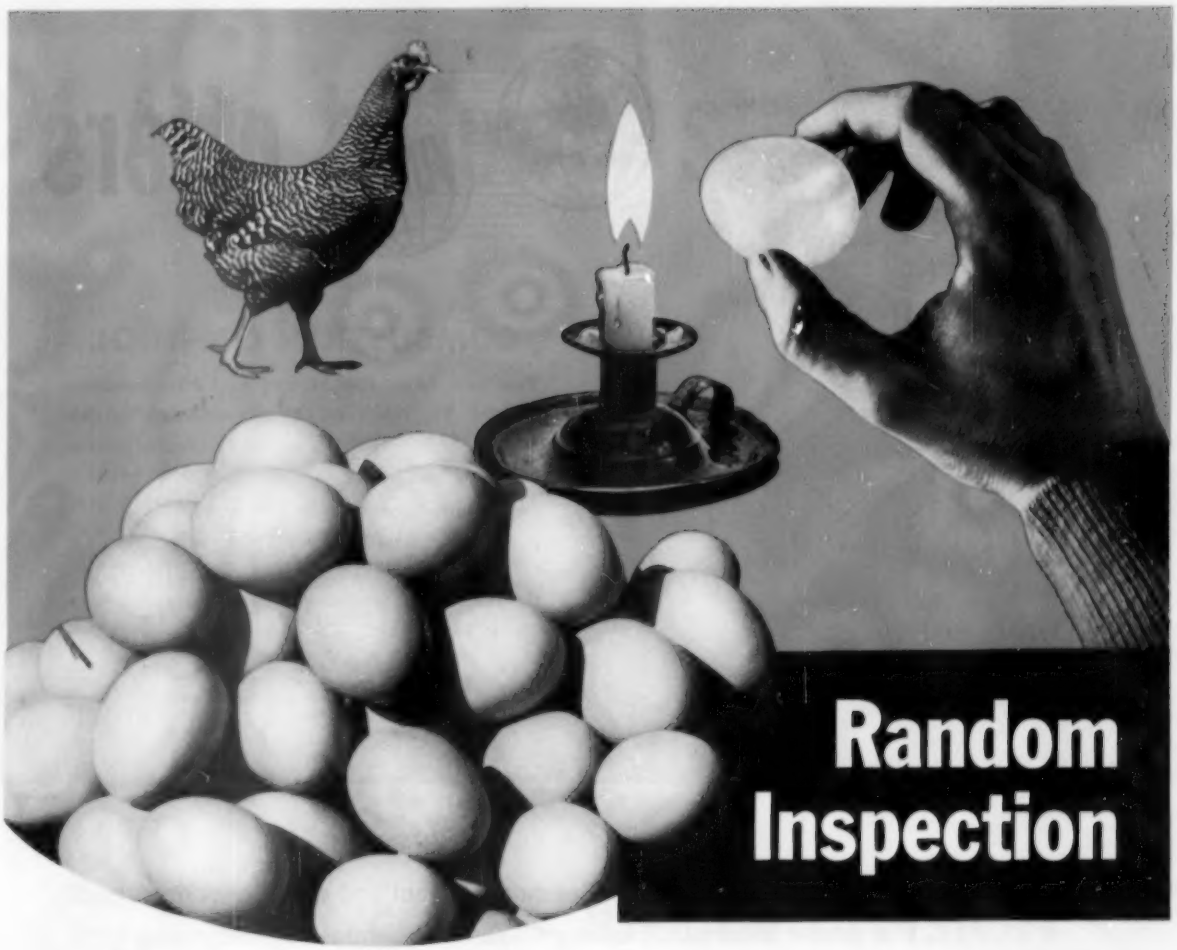
For safe, dependable drainage of superheated steam lines, get the facts about Armstrong traps. Call your local Armstrong Representative or write Armstrong Machine Works, 814 Maple St., Three Rivers, Michigan.

**ASK FOR REPRINT—**

**"Should We Trap Superheated Steam Lines"—tells the experience of trap users . . . answers your questions on high pressure trapping. Ask for Catalog J, too . . . complete data on Armstrong forged steel traps. Free on request—no obligation.**

*Application Engineered*

# ARMSTRONG STEAM TRAPS




Constant vigilance protects our reputation for quality in critical piping for power and process industries. By the practical device of radiographic inspection—*at random*, we know that our welding is always up to standard. Along with ultrasonic testing and magnetic particle examination of materials, such precaution is likewise *your* assurance when you turn to Mitchell for estimate.

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**2946 Ellsworth Street, PHILADELPHIA 46, PA.**

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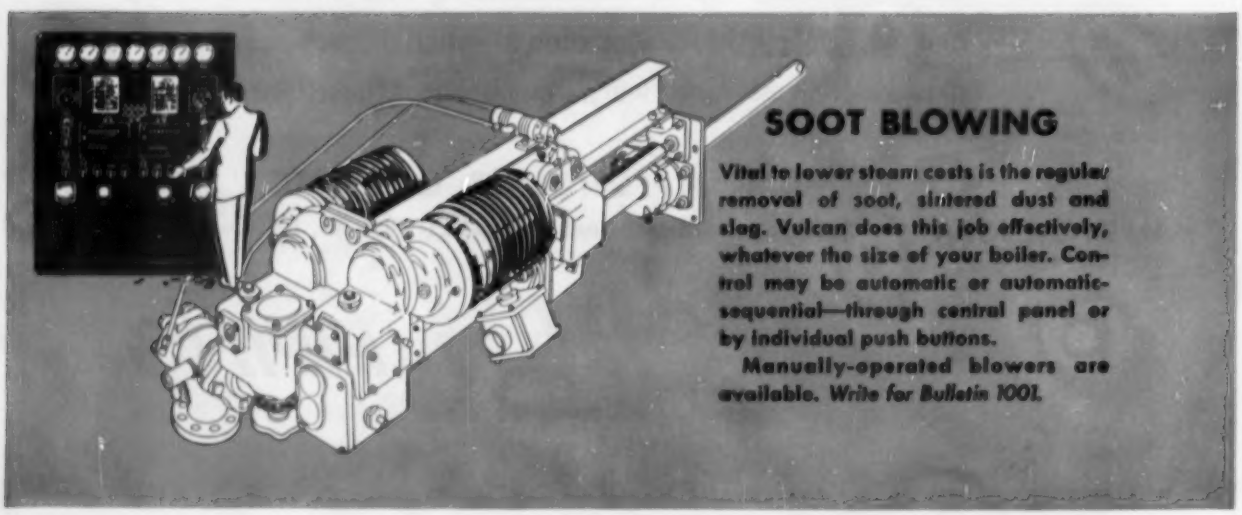
(PATENTED)

# MITCHELL PIPING
SINCE 1899

**PIPING FABRICATORS AND CONTRACTORS**

COPES
VULCAN
offers
COMBUSTION CONTROL
You can save fuel, labor and maintenance dollars by installing modern Copes-Vulcan combustion control.
You can be sure of:
—highest combustion efficiency
—constant furnace pressure
—constant steam pressure and temperature
Bulletin 1007-A describes this new approach to boiler control through
C·V+T=BBC
COPES-VULCAN+Taylor=BETTER BOILER CONTROL

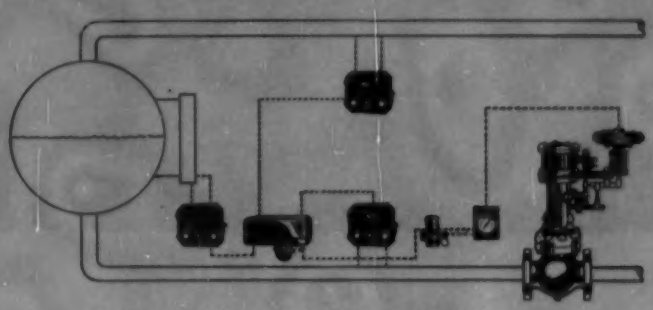
**Reduce** your steam costs. Get more efficient and safer boiler operation. Use one or more of these four Copes-Vulcan aids to offset rising costs of fuel, labor and maintenance. C • V + T offers a new approach to boiler control—with undivided responsibility from analysis to installation—and service wherever needed for the life of the installation.


SOOT BLOWING
Vital to lower steam costs is the regular removal of soot, sintered dust and slag. Vulcan does this job effectively, whatever the size of your boiler. Control may be automatic or automatic-sequential—through central panel or by individual push buttons.
Manually-operated blowers are available. Write for Bulletin 1001.

# 4 aids to lower steam costs

## FEED WATER CONTROL

**Copes feeds exactly as needed to maintain correct water level while meeting steam demands. Three-, two- or one-influence systems are available for your specific needs. Control may be independent, or tied in with combustion control. Take a look at the newest three-influence COPES instrument-type feed water control system—Type 3-L, described in *Bulletin 1013*.**



COPES VULCAN

## COPES-VULCAN DIVISION

CONTINENTAL FOUNDRY & MACHINE COMPANY

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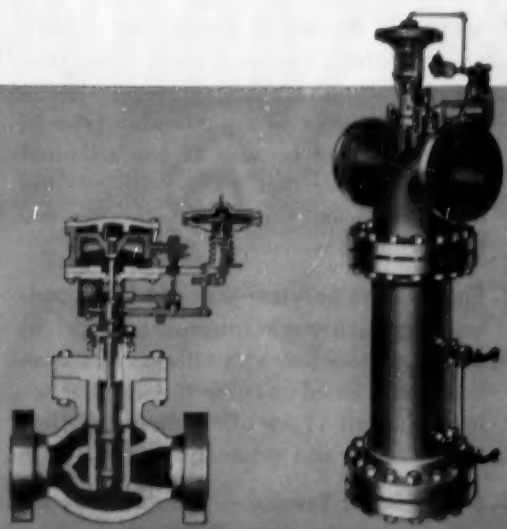
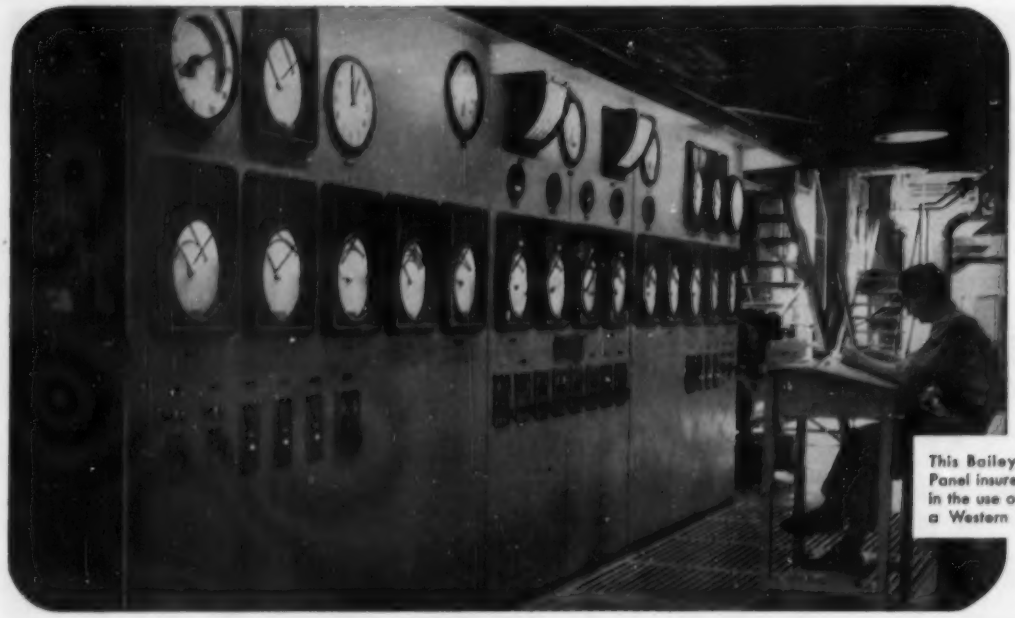
## REDUCING and DESUPERHEATING

**Copes Reducing Valves have ports characterized for specified flow and pressure conditions. Rugged construction throughout. *Write for Bulletin 477-A.***

**Copes Desuperheaters are self-contained, need no "extras" for installation. Temperature control is accurate, even on lightest flows, because cooling water is fully controlled inside the chamber. *Bulletin 405-C.***





This Bailey Boiler Control Panel insures high efficiency in the use of Fuel-Dollars at a Western Chemical Plant.

# What's Your Fuel-dollar Efficiency?

A dollar's worth of fuel has the *same potential* energy, no matter who's boiler it fires. But how much of the energy actually gets converted to a usable form depends on how you operate your boiler.

That's where Bailey Controls can help. And, here's why, we believe, you'll get better fuel-dollar efficiency with Bailey:

1. **Complete Range of Equipment—fully co-ordinated.** You need never worry that a Bailey Engineer's recommendation is slanted in favor of a particular type of equipment, just because he has a limited line to sell—or that Bailey will pass the buck for efficient control; we offer *complete* boiler control systems.

2. **Engineering Service—backed by experience.** No other manufacturer of instruments and controls can offer as broad an experience, based on successful installations involving all types of combustion, flow measurement and automatic control.

3. **Direct Sales-Service—conveniently located near you.** Bailey Meter Company's Sales-Service Engineers are located in more industrial centers than those of any other manufacturer of boiler control systems; you get prompt, experienced service with a minimum of travel time and expense.

For better fuel-dollar efficiency—for more power per fuel-dollar, less outage and safer working conditions, you owe it to yourself to investigate Bailey Controls. Ask a Bailey Engineer to arrange a visit to a nearby Bailey installation. We're proud to stand on our record: "More power to you!"

A-109-1

BAILEY METERS

**BAILEY METER COMPANY**

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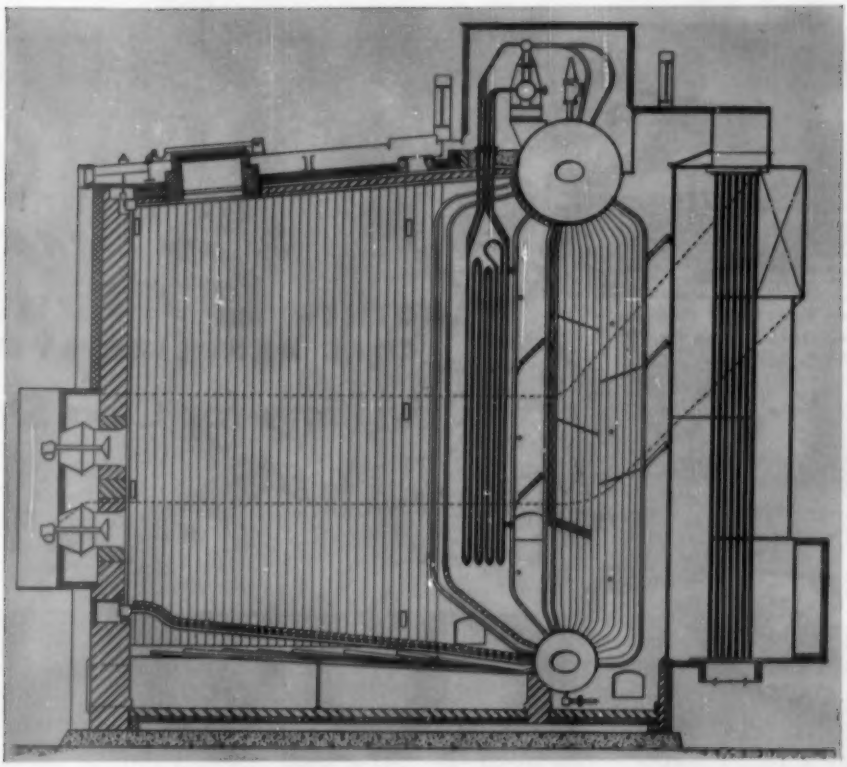
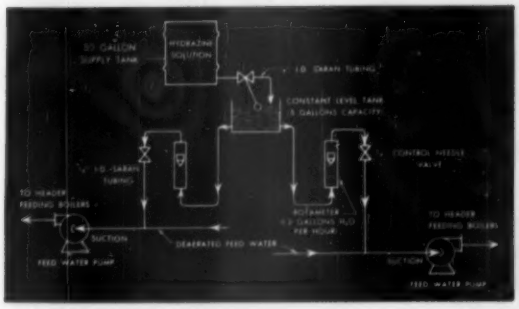
CLEVELAND 10, OHIO

*Controls for Steam Plants*
COMBUSTION · FEED WATER
TEMPERATURE · PRESSURE
LIQUID LEVEL · FEED PUMPS



# protect industrial boiler systems from oxygen corrosion with HYDRAZINE




In preventing corrosion due to dissolved oxygen, hydrazine improves the quality of process steam by reducing iron pickup—a most important consideration where color control of finished product is required. Hydrazine is now applied in high pressure and in low pressure boilers operating from 150 p.s.i. (Industrial Plants) to 2,500 p.s.i. (Central Power Stations).

Hydrazine solution is easy to handle and it does not seep through hand-hole gaskets. It can be fed through existing equipment used previously for other feedwater chemicals. Hydrazine reacts readily with dissolved oxygen to form nitrogen and water with no increase in "total solids." Moreover, hydrazine hydrate is alkaline—a 1% solution of $N_2H_4$ has a pH value of 9.9 at 77°F.

These and other advantages of hydrazine in steam systems are described in Mathieson's literature on the treatment of boiler feed water. Write for this information today.

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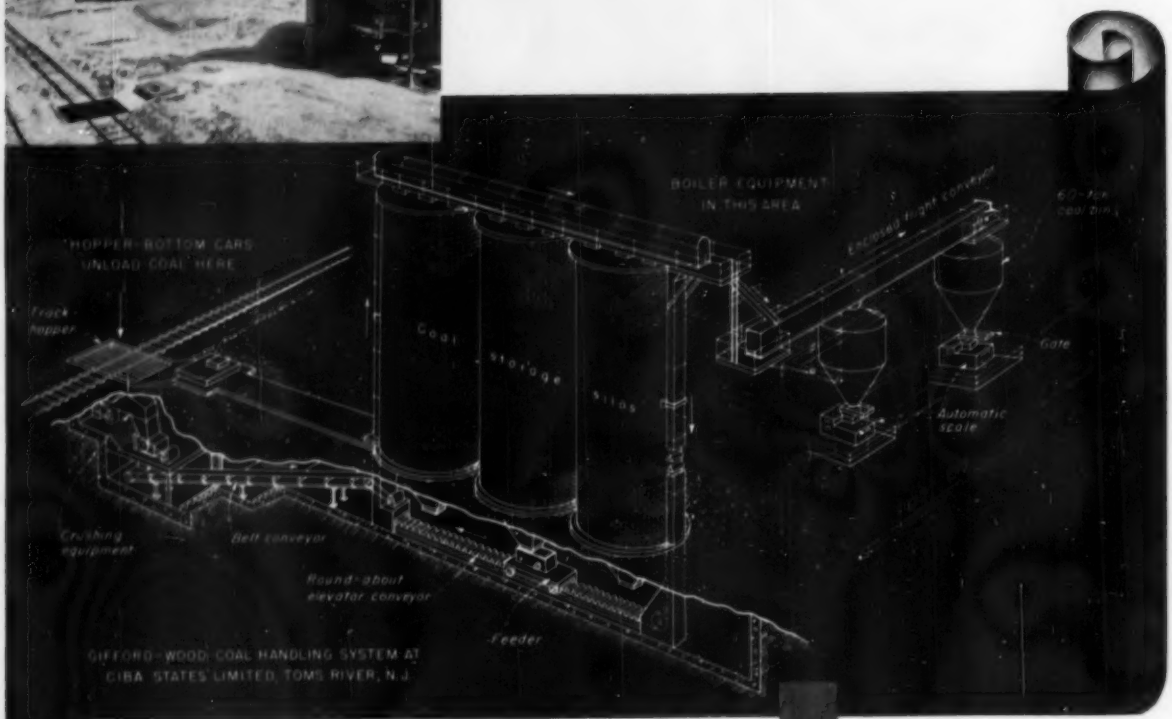
◆ Enclosed flight conveyor and 60-ton coal bin.
Under-track hopper and coal storage silos. ◆

# ANOTHER G-W AUTOMATIC COAL HANDLING SYSTEM...

## *this time for Ciba States Ltd.*




GIFFORD-WOOD COAL HANDLING SYSTEM AT CIBA STATES LIMITED, TOMS RIVER, N.J.

Now nearing completion at Toms River, N. J., is the world's most modern vat-color producing plant—and helping insure maximum power development with top economy will be the most efficient coal handling system, by Gifford-Wood. The system was designed and built by G-W engineers for Ciba States Limited, and includes unloading, storage, and feeding facilities.

For more than 140 years, G-W has met and solved materials-handling problems. This experience, coupled with planned application of the most modern equipment, is at your disposal. This project is only one example of complete design, construction, and erection under one responsibility

For details on this, or other Gifford-Wood coal handling installations, please write for Bulletin No. 300.

As diagrammed, coal passes from hopper cars through crushers, and then by means of belt and bucket conveyors, to silo storage. Transfer of coal from storage silos is by gravity feed into a movable car from which the bucket elevator lifts it, by-passing the storage silos, to an enclosed flight conveyor discharging into bins, which feed through coal scales to pulverizers.

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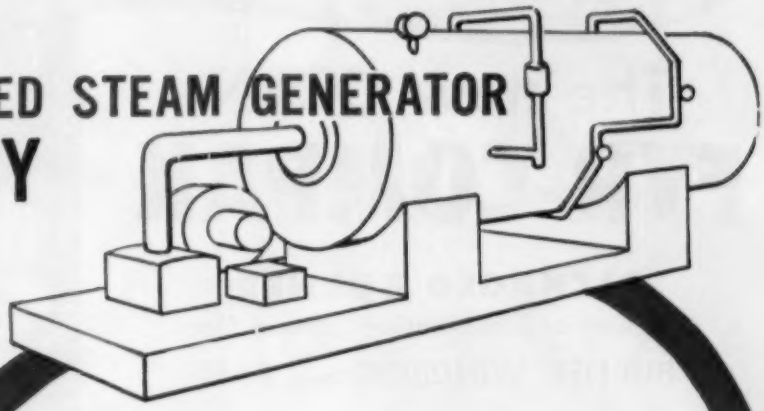
# Ideal Combination

## FOR TOP SELF-CONTAINED STEAM GENERATOR EFFICIENCY



1

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With a Nalco Service Policy and Nalco Chemicals to fit your water treatment requirements, you can keep your self-contained boilers operating indefinitely at top efficiency — without any of the costly difficulties caused by scale and corrosion. This part of the Nalco System was designed expressly to provide small boiler users with the same complete water treatment services enjoyed by thousands of the country's largest power plants. A new 4-page bulletin gives complete details on The Nalco System as applied to the modern self-contained boiler. Your copy will be sent promptly, without obligation.

**Write for Bulletin 49**

2

### Nalco SR-155 FUEL OIL ADDITIVE
### FUEL SAVING . . . CLEAN BURNERS

Nalco SR-155 is a *complete* fuel oil additive. It replaces two, three or more single-purpose additives to: (1) keep storage tanks, fuel lines and burners free of sludge and gum; (2) prevent soot formation in the firebox and flues; (3) inhibit corrosion throughout the fuel system; and (4) act as a combustion catalyst to assure complete burning of oil. Fuel savings and reduced maintenance costs usually more than repay the cost of continuous SR-155 treatment — and very little SR-155 is needed per 1,000 gallons of fuel oil! Details on Nalco SR-155 will be sent on request.

**Write for Bulletin 46**

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**THE Nalco® SYSTEM • Serving Industry through Practical Applied Science**

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# The new COEN FYR-COMPAK

PATENTS APPLIED FOR

## PACKAGED BURNER

(Oil, Gas or Combination Oil and Gas)

**BURNER, WINDBOX and FAN**

**BURNER PIPING, COMBUSTION and SAFETY CONTROLS**

***in a simple, compact Boiler Mounted Assembly***

1. For D-Type furnace arrangements with Boiler Mounted Control Center beneath (as illustrated).

or 2. For balanced furnace arrangements with Boiler Mounted Control Center to either side.

3. Minimum Trim Model—Control Cabinet only.

or 4. Standard Trim Model (as illustrated)—includes Miniature Panel above Control Cabinet with addition of flush mounted Boiler Gage, Draft Gage, Fuel Pressure Gages and Remote Manual-Automatic Control Station.

5. Fully Automatic or Semi-Automatic (push button elec-gas ignition).

The New COEN FYR-COMPAK includes **all** the many advantages of the efficient wide range COEN PAC-O-MATIC Package Burner plus these **outstanding innovations:**

- Integral Flush Front Windbox-Fan Housing with **Centrifugal** Fan.
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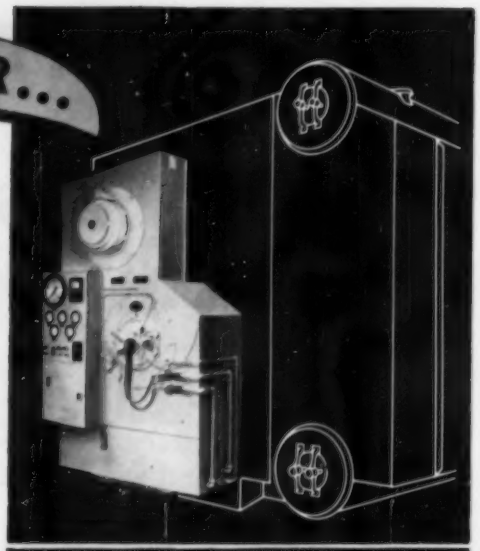

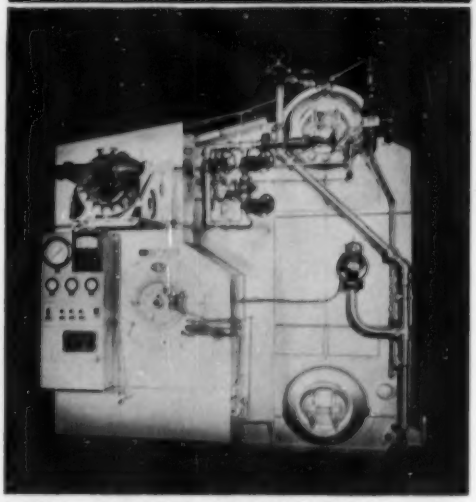

*Upper Photo* — Combination Gas and Oil for CE "VP" 30,000 pph package boiler.

*Lower Photo* — Oil only — Turbine drive for CE "VP" 30,000 pph package boiler.

**FYR-COMPAKS sold and on order for Combustion Engineering "VP" package boilers during 4 months since its introduction totaled 15 as of March 15th.**

Write for COEN FYR-COMPAK Specifications and *"Why Coen?"* (a complete checklist of COEN features and advantages).

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COMBUSTION ENGINEERS • DESIGNERS • MANUFACTURERS

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**MIDWEST**
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The Walling Co.
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**GULF SOUTHWEST**
J. Newell Royall
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**MOUNTAIN STATES—DENVER**
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So. Denver Station, Denver, Colo.

**MOUNTAIN STATES—SALT LAKE CITY**
Pace Turpin Company
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**NORTHWEST**
Northwest Industrial Service Co.
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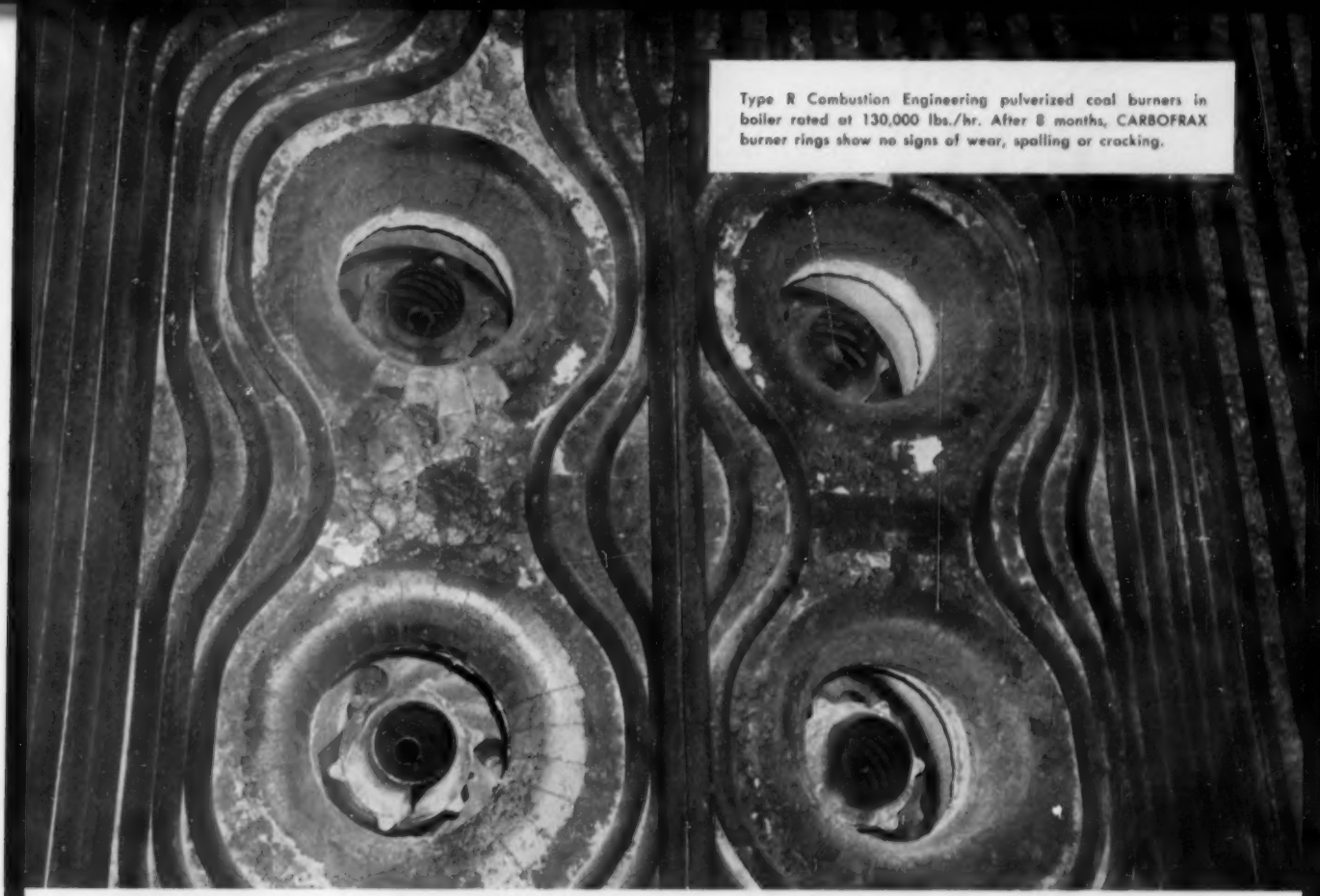
**SOUTHWEST**
A.H. Merrill Engineering Co.
1238 S. Atlantic Blvd., Los Angeles, Cal.



Type R Combustion Engineering pulverized coal burners in boiler rated at 130,000 lbs./hr. After 8 months, CARBOFRAX burner rings show no signs of wear, spalling or cracking.

## This company proved to its own satisfaction that...

## CARBOFRAX® burner rings outlast other types!

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They used a simple test. Burner rings of various refractory materials were placed in service.

Long after removing all others, one ring continued in use. This was built of CARBOFRAX silicon carbide shapes. The ring went on and on and on, proving its worth to the operator's own satisfaction.

*In burner rings, in numerous other trouble spots,* CARBORUNDUM's *Super Refractories can improve boiler efficiency . . . can relieve many operating headaches. More information is given in our booklet on Super Refractories for Boiler Furnaces. For your free copy write Refractories Division, The Carborundum Company, Perth Amboy, N. J. Dept. E45.*

CARBORUNDUM

Registered Trade Mark

# HALL INDUSTRIAL WATER REPORT

*Hall Laboratories, Inc.—Consultants on Procurement, Treatment, Use and Disposal of Industrial Water*

Volume 3 APRIL 1955 Number 2


## *It Takes a Lot of Water Conditioning To Deliver the Kilowatts*

Current expansion in the public utility field to supply industry with more power and to bring electrification to greater areas demands careful planning for future water requirements, as well as active attention to existing water uses. Experts in utility station management turn to experts in water management for continuing consultation on water treatment and control.

Hall Laboratories now performs this service for some three hundred utilities, many of them on a system-wide basis.

### Design of New Facilities

Constructors of a new utility plant on the West Coast made use of Hall's headquarters engineers in a three-way consultation to centralize information on: water availability and requirements from the plant; water characteristics from Hall field engineer E. R. Lang; and plant design from the constructors. A realistic report on cost and operation of suitable pretreating equipment resulted from the analysis.

The station has recently started operation with continuing supervision of water conditioning practice by Hall Laboratories.

### Tailoring Water to Fit a Plant

Another western utility, whose existing plants were operating with Hall Service, withheld a final decision on the location of a new station until an adequate water supply could be developed.

Again, working with the constructors and the client, Hall Laboratories first analyzed samples from all available sources over a time period calculated to include representative conditions throughout the year. One sample was even taken during a flash flood, and provisions made for such extreme conditions.

With the data thus collected and the information on system requirements from the client and constructors, Hall staff engineers S. R. Osborne and A. M. Henricks went to work on recommendations for water treatment facilities. A detailed report covered preparation of water for: recirculating cooling water; cooling water for bearings; feedwater to the evaporator and drinking water. The Hall report included estimated comparative costs of alternative chemical treatments and diagrams indicating all equipment with specifications of capacities to simplify study of the various alternatives.

This power station has just gone into operation with Hall field engineer R. M. Tarr on the job to help plant engineers and chemists set up the exact conditions they need for the best operation of their new facilities.

### Minimizing Treatment Costs

In other cases, plant surveys by qualified water-treatment engineers can obviate the purchase of costly equipment.

Hall engineers J. E. Summerville and M. C. Scott worked on a problem of this kind with a southeastern utility plant supplying a large rural area. The plant drew its water from three wells. Soluble iron and iron bacteria in the well water caused iron deposits in the plant water lines, recirculating cooling system and heat exchangers. Lines carrying cooling water to bearings had to be cleaned every three months to prevent complete plugging. Plugging of oil coolers occurred.

Iron removal would have involved a capital expenditure of $20,000 to $25,000 for equipment plus an annual chemical cost of $15,000 to $19,000. When Summerville and Scott estimated comparative cost of $1800 for equipment and $8000 for chemicals to control iron by Calgon® treatment, the plant deferred consideration of the pretreatment facilities.

Later reports showed that the co-operation of the plant personnel in carrying out the recommendations for controlling the iron and organic growths in the system had paid off. The water side of the condenser was free of deposit, the cooling tower was in good shape and oil coolers no longer plugged. Organic growth was under control.

* * *

Delivering kilowatts to all types of customers is the business of electric power stations. By adding the broad experience of Hall Laboratories to the specific knowledge of their own technical staffs, these companies feel better prepared to keep water troubles from interfering with production of power.

---

## *Boiler Feedwater Studies*

Hall Laboratories participated in two papers sponsored by the Joint Research Committee on Boiler Feedwater Studies and presented at the 1954 annual meeting of the American Society of Mechanical Engineers in New York. M. D. Baker of West Penn Power Company and V. M. Marcy of Hall reported on "Hydrazine As An Oxygen Scavenger—A Progress Report on Tests at Springdale Station." J. D. Ristroph of Virginia Electric and Power Company and E. A. Yorkgitis of Hall presented a paper on "Controlling Iron and Copper Pick-Up with Neutralizing Amines." Preprints of the papers are available in limited quantities from the A.S.M.E. under No. 54-A-271 and No. 54-A-262, respectively.

---

## *Industrial Water Problems Require Special Handling*

There are no "stock answers" to industrial water problems. For information, write, wire or call Hall Laboratories, Inc., Hagan Building, Pittsburgh 30, Pa.

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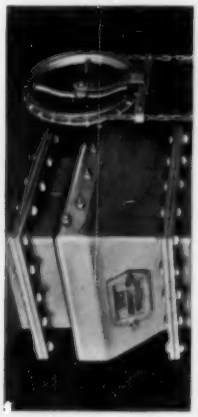
*Water is your industry's most important raw material. Use it wisely.*

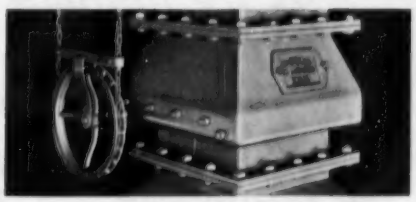

HALL LABORATORIES, INC.—A SUBSIDIARY OF HAGAN CORPORATION, PITTSBURGH, PENNSYLVANIA

# Any way you look at it . . .



## *you get more value when you*

## *buy the New* S·E·CO. Coal Valve



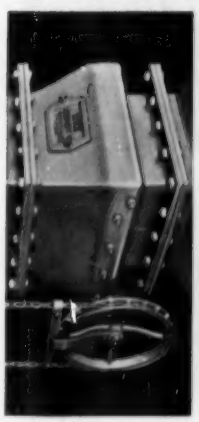
Any way you look at it the new S-E-Co. Coal Valve gives you more value . . . more life expectancy . . . more dependability . . . more ease of operation.

More life because of its heavy construction. The body is made of ⅜" thick steel with ¾" thick flanges. More life because stainless steel is used to combat corrosion — as gate liner, for pinions, gate rollers and grease seal retainers.

More dependability of operation due to the unique ladder racks and multiple faced pinions, both of which are self-cleaning so that tooth engagement is sure. More dependability since two racks are used, one on each side of gate, located far above normal coal flow, to assure straight line gate movement without jamming or binding.

More ease of operation due to large gate supporting rollers equipped with ball bearings and grease seals for pressure lubrication from outside the valve body.

The best costs little more than the average. A S-E-Co. representative would be happy to talk it over with you.



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**STOCK Equipment Company**

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The Flexitallic Gasket that is engineered for your specific application has an ability to take care of itself and its job. It is self-adjusting to changes in operating conditions. It has just the right amount of "give" and "take". And here are the reasons:

Since 1912 — for forty-three years — Flexitallic engineers have concentrated on one product, spiral-wound gaskets—and on one goal, the perfection of those gaskets. It is the basic design and the manufacturing process, as much as the materials, that determine gasket characteristics. The engineering, the special machines and the quality control employed at Flexitallic give you the maximum in gasket performance and permanence — which, in turn, give you safety, low down-time and economy of operation.

Each Flexitallic Gasket is designed and engineered to meet specific conditions of thermal and physical shock, corrosion, vibration, weaving and unpredictable joint stresses. Spirally-wound V-crimped plies of required metal with alternating plies of proper filler result in a resilient gasket having characteristics of a calibrated spring.

Flexitallic Gaskets are at highest efficiency when bolted up cold at a predetermined load. For all pressure/temperature ranges from vacuum to 10,000 lbs. from extreme sub-zero to 2000°F. For all standard joint assemblies. In four thicknesses for special requirements: .125", .175", .250", .285". In diameters to 84" O.D.

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# Editorials

## A Look Into the Future

The recently completed American Power Conference, reported in this issue, pp. 62–68, maintained its now well established reputation as the outstanding national forum for the power industry in the country. Two particularly interesting papers on the difficult task of electrical system planning served up some valuable food for thought on the future of the power industry.

One of these papers, that by **H. L. Melvin,** chief consulting engineer, Ebasco Services was especially illuminating.

Out of his talk came the conclusion that gas and oil are recognized as becoming premium fuels for electric production and that coal will continue to be the base fuel used by the industry for the next several years. Atomic energy will be another heat source to be used, as, when, and where it becomes economic. This speaker held that in evaluating atomic energy too little emphasis is placed on investments involved, the resulting fixed charges, and, the fact that the thermal end of a power plant, though large and important, is not the major component of a power system. Between the customers and raw energy sources comes the power system with its distribution and transmission lines, substations and power plants.

The next ten to twenty years, it was said, mark the beginning of another era of development. We are no longer dealing with the doubling of the tens, twenties and forties of generating capabilities but of doubling the hundreds. Fortunately the manufacturers have been foresighted and, with the pressures from the industry, have made remarkable strides in the design and production of larger and more efficient equipment. Continued progress in sizes, said this same speaker, will certainly be forthcoming along with increasing manufacturing capacity, and the proved availability of these large units.

In Mr. Melvin's eyes the most important problems to be faced are in the distribution of the power to the customers and by the customers. Here, says Mr. Melvin, lies an opportunity to arrive at new standards for higher secondary-voltage services that will better suit the customer and the power industry in meeting the higher load intensities of tomorrow. Generally there is too much tendency to draw a line of demarcation between transmission and distribution. Transformations, in Mr. Melvin's opinion, should be reduced to a minimum and layouts made simple. Extra high voltages will prove economic and if the power plant can be placed at the mine mouth avoiding the hauling of coal, electric transmission will be competitive with rail or barges for coal or piplines for gas and oil for distances up to 200 to 400 miles.

So long as the per kilowatt costs of units and plants decrease capacities of units can hardly become too great for large interconnected power systems even at this date. Transportation of the equipment, Mr. Melvin feels, will probably become the bottleneck unless continued progress can be made in reducing the pounds of material per kilowatt.

All in all the above thumbnail survey of the power industry's future points up the value of highly concentrated conference programs designed to serve a specialized industry. Before such a forum appraisals of the industry's future such as Mr. Melvin's can stimulate thinking among those best situated to influence that future. It will be interesting, indeed, to follow the course of the power industry against the above predictions.

Fig. 1—Aerial view of Vermilion Station showing reservoir in foreground, cooling towers, left background.

# Vermilion Station, Features Cooling Tower Economies in Plant Design

By R. L. MARTIN* and L. APPELT† and S. L. CHAPIN††

Illinois Power Company — Sargent & Lundy Co.

**The growth of a heavy load in the Danville, Illinois, area led to a study of a new generating station situated near the load center. This study indicated definite economic advantages for a cooling tower station as against a river one. The design features of the Vermilion Station reported here give considerable details on the workings of this cooling tower system.**

THE new Vermilion Power Station of the Illinois Power Company is located on a branch of the Vermilion River approximately ten miles northwest of Danville in central Illinois, near the Indiana state line. Unit 1 is a 75,000-kw unit and will go into operation in April 1955. Unit 2 will be a 100,000-kw unit and is scheduled for operation in October of 1956.

* Manager of Power Plant Design and Construction
† Mechanical Engineer
†† Electrical Engineer

*General Plant Description*

The Vermilion plant consists of a main building, river water pump house, reservoir water pump house, water treatment plant and cooling tower. Yard construction includes a large demineralized storage tank, tractor garage, breaker building, track and reclaiming hopper, thawing pits, blower and oil pump house for thawing pit equipment, a diesel oil storage tank, two small service water storage tanks, a 700,000,000-gal reservoir, sulfuric acid storage tank, cooling tower control building, 69-kv and 138-kv switchyards, track facilities, coal stocking-out bin and a 300,000-ton coal storage yard.

Plant capacity is provided by one 525,000-lb-per-hr controlled circulation boiler to provide steam at throttle conditions of 1450 psig, 1000 F; one turbo-generator rated at 75,000 kw; and a coal-handling system designed for ultimate capacity of 400 tons per hr, but operating initially at 300 tons per hr.

The main building houses the boiler and turbine-generator together with all their necessary auxiliaries, coal bunkers, elevator, traveling bridge crane, control

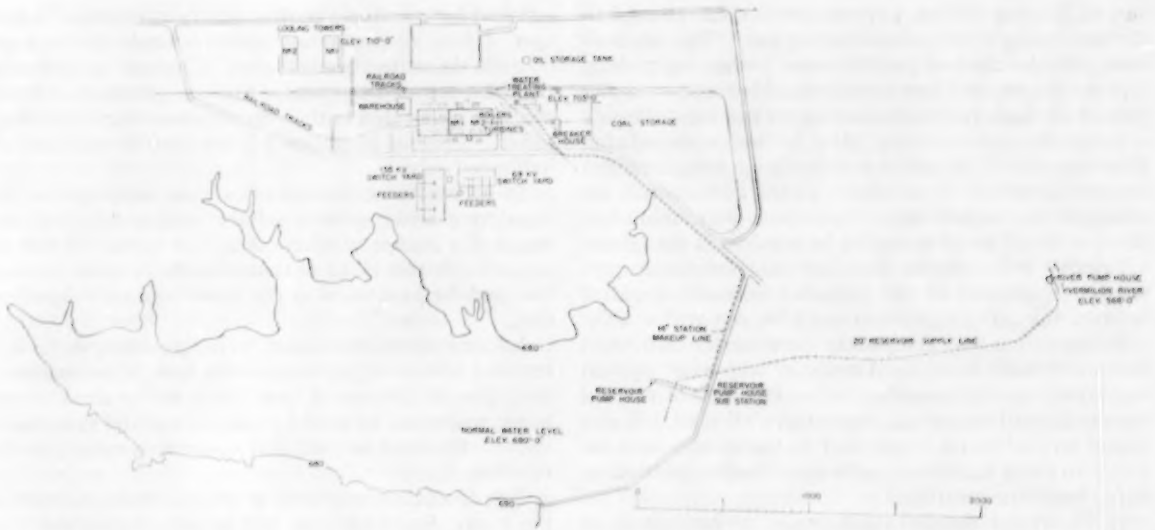



**Fig. 2—General plot plan of station and major water arteries such as river pump house, reservoir pump house, water treatment plant.**

room, machine shop, laboratory, offices and storage rooms. It is supported on a structurally designed reinforced concrete slab and a steel-framed superstructure with concrete slabs and open bar grating galleries, precast concrete roof slabs and composition siding in the boiler room, and temporary walls and brick walls in the office building and turbine room. A masonry stack is provided which will handle Units 1 and 2.

### *Selection of Station Site*

The Danville area is a heavy load distribution center for Illinois Power Company's system. When it was decided to build a station to meet this load, the choice between a cooling tower station near Danville and a river station on the Wabash River in Indiana had to be made. Economic studies indicated that the cooling tower station near Danville was more desirable.

### *Station Water Supply*

Water is pumped from the middle fork of the Vermilion River into the 700,000,000-gallon storage reservoir by two 4500-gpm, 200-ft. head horizontal centrifugal pumps. These pumps, together with their controls, are housed in a water-tight concrete pump house. They are equipped with safety shutoffs to stop the pump in event of loss of discharge flow or failure of sump pump. Since the pumps are operated normally at a suction lift, a motor-driven vacuum pump is provided for priming.

One pump will be operated whenever river flow is 10 cfs above minimum flow of 10 cfs and two when flow is 20 cfs above minimum.

For storage of station make-up water, consideration was given to the construction of a dam across the river but because of the expensive construction which would require provisions for allowing flow during flood periods and acquiring land that would be flooded, it was decided to build an off-river storage reservoir.

The storage reservoir was formed by constructing an earth dam across the mouth of a natural ravine adjacent to the plant site. The deep portion of the dam is about 400 feet long and about 75 feet deep with dikes extending to a total length of 2500 feet. Surface area of the reservoir when full is 120 acres.

It is estimated that the reservoir storage capacity of 700,000,000 gallons will handle a station capacity of 275 megawatts operating at a 60 per cent load factor for a period of 120 days without inflow. Conservative allowances were made for evaporation, seepage and siltage. Experience will no doubt indicate that a longer period of operation at this load is possible without inflow.

Two 2500-gpm vertical pumps are located in the reservoir pump house. Each pump has sufficient capacity to supply makeup water for two units. Provision has been made for a third pump, should future expansion require it. Vertical pumps were selected for this service since a possible water level variation of 47 ft must be anticipated to utilize maximum storage capacity of the reservoir.

The reservoir pump house is likewise of concrete construction; it is 22 ft, 4 in. in outside diameter and has a wall thickness of 8 inches. Slots are provided in the face of the structure to insert double screens or to blank off the lower portion of the intake opening when reservoir elevation is high. Access to the pump house is by a bridge 185 ft in length.

### *Water Treatment*

Station water supply is from the reservoir. All water for station use, except that to the ash pit seals, is treated by the cold lime-soda ash method in a concrete precipitator basin. The precipitator rating is 1800 gpm.

Water from the precipitator is collected in a clear well from which two 1800-gpm pumps take suction and pump the water first through the filters and then into a 12-in. makeup line which is connected to the 54-in. Unit 1 circulating water pump suction line. Two 1200-gpm station service water pumps take their suction from the 12-in. makeup line. Station service water is used for

various bearing cooling purposes and is then returned to the circulating water pumps suction line. This arrangement provides the best possible water for bearing cooling.

A portion of the filtered precipitator effluent is further treated for boiler feedwater makeup by passing it through a complete demineralizing plant. The demineralizing plant consists of two cation and two anion units arranged to operate initially in parallel. Piping and controls are arranged to permit series operation with minimum changes should series operation be required in the future. Alkalinity reduction in the lime-soda treatment permitted elimination of the degasifier normally installed between the cation and anion units for removal of $CO_2$.

Regeneration is completely automatic. No acid measuring tank is required since a "step-wise" system employing an acid pump and solenoid valves of varying sizes to control regenerant concentration is used. Warm cation treated water is supplied to the caustic soda injector to bring the caustic soda regeneration solution up to optimum temperature.

A 75,000-gal demineralized water storage tank at grade is provided for Units 1 and 2.

### *Cooling Tower*

Unit 1 cooling tower is designed to cool 53,000 gpm from 101.5 F to 86 F at a wet bulb temperature of 76 F. The tower is of the cross-flow induced-draft type with nailless redwood fill. Nine cells are provided with one 22-ft dia fan per cell driven by a 50-hp motor at a speed of 162 rpm.

Two-speed motors are used to drive the fans to take advantage of lower power input at light loads and low ambient temperatures during winter operation. Selection of fans and operating speed is made at the gage board in the central control room. Controls for reversing the fans for de-icing the tower are provided. These controls are located in the control house near the cooling tower. Reverse operation of the fans is provided at half speed only.

To prevent precipitation of calcium carbonate in the circulating water system, sulfuric acid is added at the circulating pumps suction. A pH of 6.5 to 7.5 will be maintained, this being optimum both for scale prevention and for protection of the tower against delignification.

Ash sluicing water is taken from the cooling water system and will act as the major blowdown or deconcentrator. Should additional blow-down be required, circulating water can be used for ash pit seal and then run to waste. (Normal ash pit seal water is returned to the reservoir.)

To prevent algae growth in the condenser as well as the tower, liquid chlorine will be fed intermittently to the circulating water just ahead of the pumps. The chlorinating equipment is located in the water treating building and will have sufficient capacity for Units 1 and 2.

### *Steam Generator*

The steam generator is of the radiant-type controlled-circulation design and has a normal rating of 525,000 lb per hr at 1500 psig, 1000 F main steam temperature with reheat to 1000 F. It is of the semi-outdoor type; the rear of the air heater, roof and the side above the office building roof are of outdoor construction. Retractable

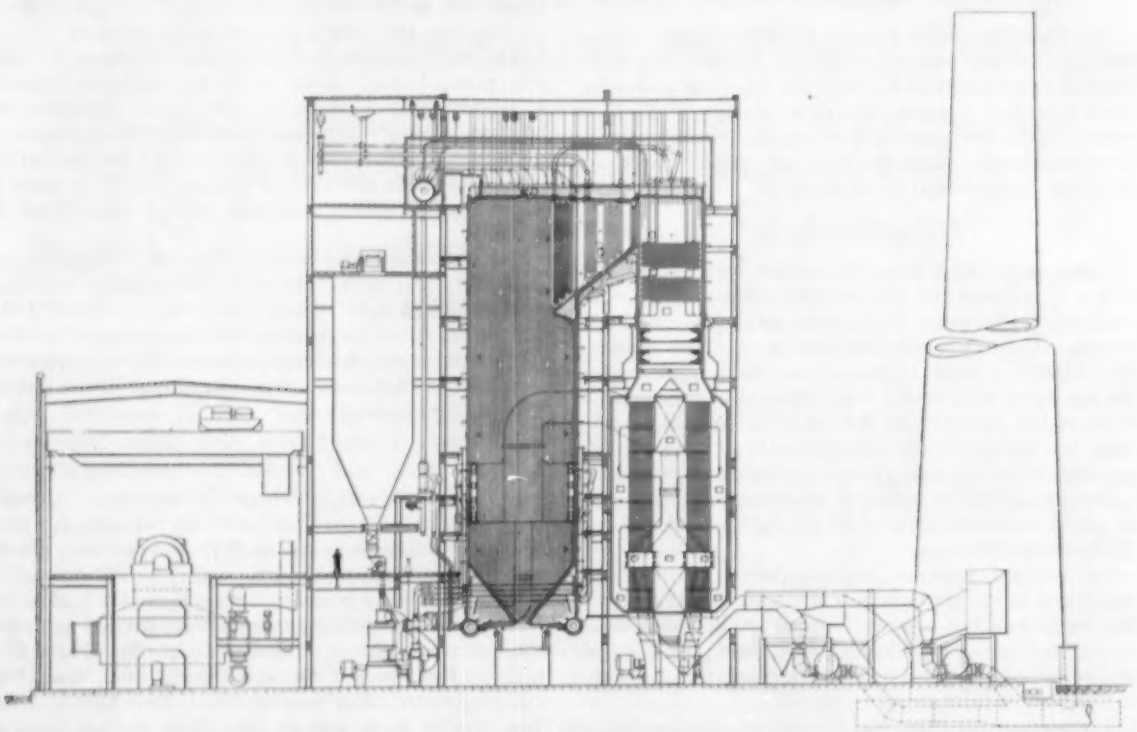


**Fig. 3—Cross section of the station shows emphasis on ground level construction.**

soot blowers of full furnace width are installed in addition to the necessary wall blowers.

Pulverized central Illinois bituminous coal is the primary fuel; however, high-pressure oil burners of sufficient size to generate 250,000 lb of steam per hr are provided. Provision is also made to burn gas should it become available in the future.

To carry light loads for long periods satisfactorily, it was decided to equip the boiler with four mills rather than the normal three mills for a boiler of this size. The contract stipulates that minimum steam load with all burners in operation is 150,000 lb per hr without oil stabilization and 50,000 lb per hr with oil stabilization.

To minimize leakage of boiler circulating pump seal injection water into the boiler, a differential pressure controller is installed in the injection water supply to maintain a 50-psi differential across the supply and circulating pump discharge. Injection water drains are returned to the direct-contact heater through a back-pressure regulating valve to minimize flashing in the return line.

Special ducts containing hoppers and drain outlets are installed under the tubular air heater. These ducts permit water washing of the lower air heater sections at light loads.

### *Turbine and Controls*

The turbine is a 75-mw, single-spindle, 3600-rpm, tandem-compound, double-flow reheat unit designed for steam conditions of 1450 psig, 1000 F initial and 1000 F reheat temperature operating at 1.5 in. Hg back pressure.

The generator is rated at 60,000 kw, 0.8 pf, 75,000 kva, 13,800 volt, 3-phase, when operated with 0.5-psig hydrogen pressure. Generator capability is 90,875 kva at 138 kv with 95 F cooling water when operating at 30-psig hydrogen pressure. The exciter is direct connected and operates at 250-volt d.c.

Normal control of the turbine is accomplished from the central control room. However, a starting up panel adjacent to the turbine was provided. This panel contains various pressure gages and alarms that are of particular importance during start up as well as the valve testing panel, hydrogen system controls, and turbine supervisory instruments. Hydrogen pressures are transmitted pneumatically from panel to control room.

A 55,000-sq. ft surface condenser serves the unit. The condenser was shop tubed and shipped to the station site in two halves. Field erection consisted of placing and bolting together the two halves. The condenser inlet is welded to the turbine exhaust. A removable steel panel in the south wall of the turbine room permits pulling condenser tubes.

Two 26,000-gpm horizontal circulating pumps serve the condenser. These pumps are of the outdoor type and are located on the I-D. fan slab north of the boiler room wall. Steel supply and return lines 54 in. in diam. are run overhead within the building. The return line to the tower is also steel. The suction line from the tower to the pumps is concrete.

Two 1000-gpm vertical hotwell pumps remove condensate from the condenser. To maintain minimum level in the hotwell an 8 in. diaphragm-operated valve is installed in the condensate line beyond the steam-jet air-ejector coolers.

Two hydraulically operated hogging jets are provided for evacuating the steam space during start up. Ash sluice water is used as the operating medium for the jets. Drains are returned through properly vented lines to the circulating pumps suction.

### *Feedwater Cycle*

The feedwater heating cycle consists of five heaters, two low-pressure, one open deaerating, and two high-pressure. Two full capacity vertical condensate pumps are provided. Drains from No. 2 heater are cascaded to No. 1 heater. A heater drain pump takes the drainage from No. 1 heater and introduces it into the main condensate line between No. 1 and 2 heaters. In case of heater drain pump failure, drains are automatically overflowed to the condenser.

Two motor-driven full capacity feed pumps are installed. Speed control is through a hydraulic coupling. Boiler water level is maintained by a three element control system. The feedwater regulating valve is located on the main floor ahead of the high pressure heaters, making easy accessibility for emergency operation. To insure minimum flow through the feed pumps, each is equipped with a two-in. recirculating valve to maintain a flow of 105,000 lb per hr. Metering for recirculation control is accomplished by means of an orifice plate in the pump suction line.

Makeup to the feedwater system is added to the con-

Continued on page 48

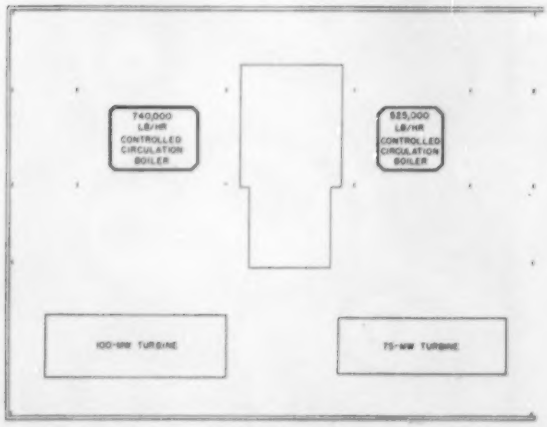



Fig. 4—Plan view of boiler units, No. 1 and 2.

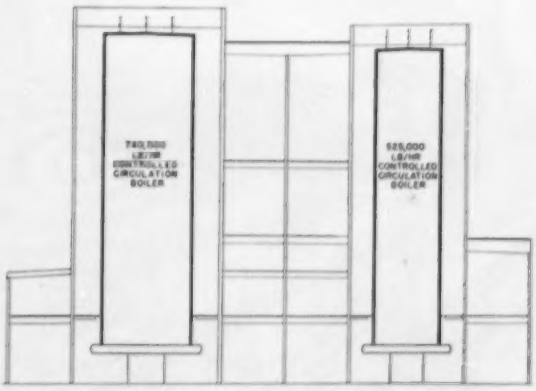
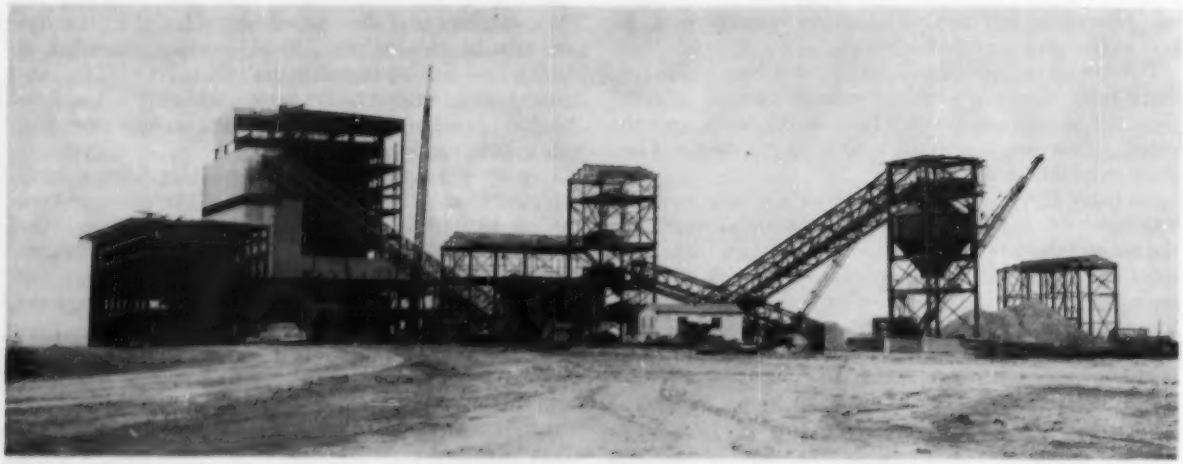



Fig. 5—Elevation view of two boiler units in Fig. 4.



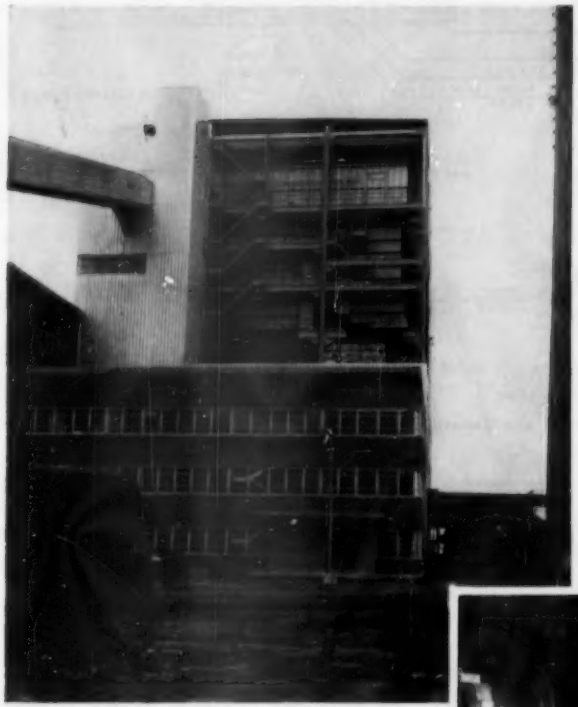
General view of plant construction from the coal storage yard

East end of reservoir

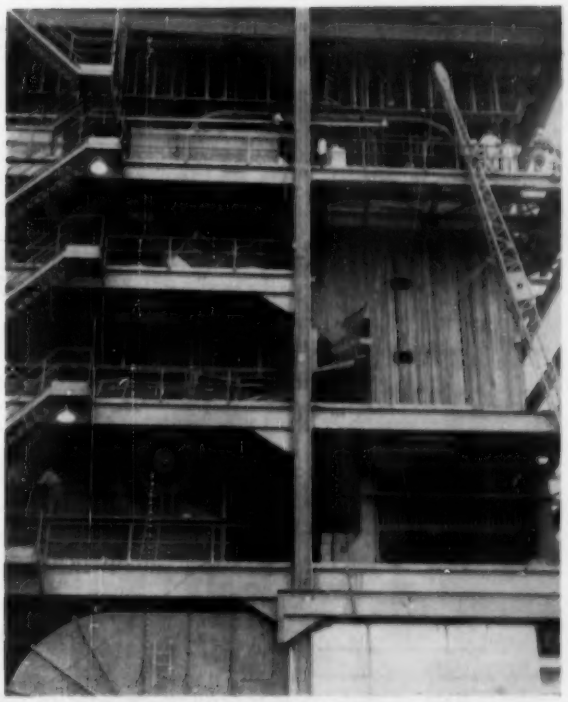
Cooling tower

River pump house

## Construction Views of the Vermilion Station of Illinois Power Company



East elevation of boiler house



East side of boiler

Setting of turbine wheel

Ash sluice piping

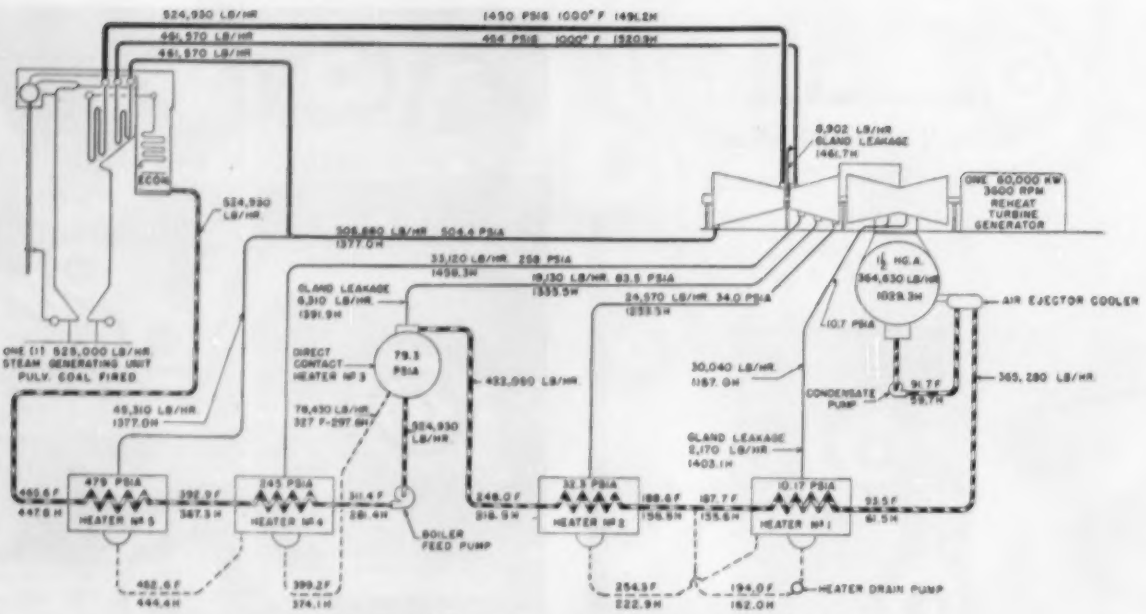



**Fig. 6—Heat balance diagram of the Vermilion Station**

denser. Rate of makeup is controlled by level in the storage section of the deaerating heater.

### *Central Control Room*

An air-conditioned central control room located between Boiler 1 and Boiler 2 houses cubicle-type panels from which operation of the first two boilers will be controlled. All generators and high voltage feeders, future as well as present, will be controlled from this room, but a future boiler and turbine control room is planned for Units 3 and 4. Auxiliary metering panels, d-c and lighting distribution panels, mill and forced draft temperature controllers and other miscellaneous equipment are located in a space directly above the control room. Louverall ceiling lighting and the use of anti-glare glass on instruments will assure uniform reflection-free illumination on all panels.

Automatic area load control, which includes telemetering of all essential information to the system load dispatcher by leased wire, will provide means for adjusting total system load, as well as division of load between units according to system demand.

A 20-ton mechanical air conditioning unit provides properly conditioned air for the central control room operating level. Heating coils and a humidifier are also installed for use when required. Filtered air is supplied to the mezzanine for ventilation.

### *Coal-Handling System*

Principal source of coal supply is from Central Illinois mines. Coal will be delivered to station in railroad cars and unloaded into a track hopper. A car shakeout will be used to speed up the unloading operation. The coal-handling system will be operated initially at 300 tons per hour. Capacity of the system can be increased to 400 tons per hour should future expansion demand. Four oil-fired thawing pits are installed to handle frozen coal along with barrier walls to prevent loss of heat and maintain ignition at the torches.

Coal is taken from the track hopper to the breaker by belt conveyor. Coal can then be taken directly to the station bunker or to the stocking-out bin for transportation to the storage area by carryalls. Bunker capacity is 1050 tons; yard storage capacity is 300,000 tons.

Coal is weighed by a weightometer on the belt that takes the coal from the track or reclaiming hopper to the breaker. No coal scales are provided at the bunker outlets. A coal sampler samples the coal continuously from the over bunker conveyor. Screw conveyors take the sample to a grinder and return the rejected sample to the belt conveyor.

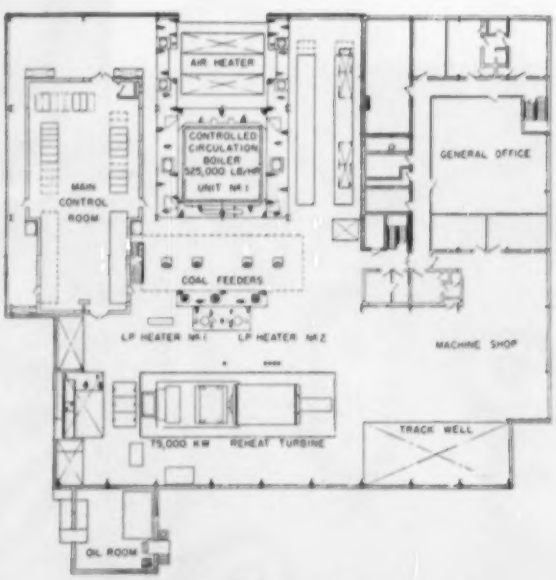



**Fig. 7—Flow plan of the station.**

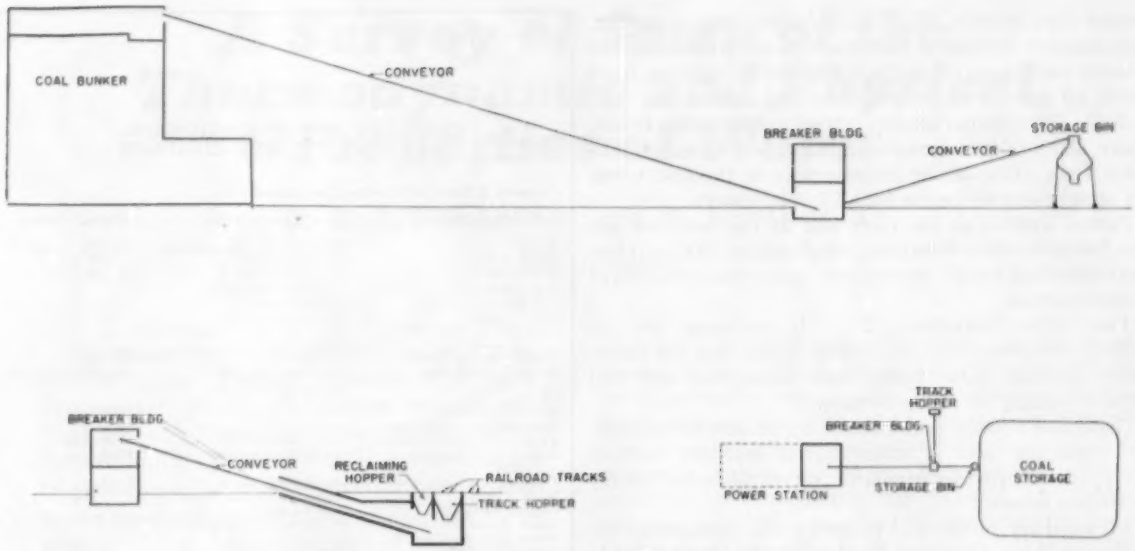



**Fig. 6—Coal handling system is shown in the above.**

For reclamation of coal from storage pile (or for receiving coal in truck shipments), a reclaiming hopper is provided adjacent to the track hopper. A belt feeder delivers coal from the reclaiming hopper to the belt conveyor which takes coal from the track hopper.

### *Ash-Handling System*

Bottom ash and fly ash collected in the stack base dust collector and air heater hoppers are hydraulically sluiced to a natural ravine north of the station. The ash sluice pumps take suction from the circulating water return.

### *Domestic Water*

It was originally planned to use well water for domestic water purposes. During the construction period, it developed the wells were not a reliable source so it was decided to use reservoir water for this purpose. Filtered precipitator effluent is further treated by hypochlorinating and minimum contact time is assured by storage in an overhead domestic water storage tank.

### *Office Building Cooling*

It was originally planned to use well water for cooling the office building. Failure of this source as a dependable supply caused the installation of a 60-ton mechanical refrigeration unit.

The compressor is of the radial type equipped with built-in capacity control for unloaded starting and 7-step capacity regulation and is motor driven. Refrigerant condenser is of the water-cooled type.

### *Electrical System*

Power is delivered from the generator through a 4500-amp isolated-phase bus to a 65,000/86,667-kva, 3-phase forced-air-cooled transformer outside the turbine room wall. Tapped off the generator bus, also through an isolated-phase bus, and a magnetizing current interrupting disconnecting switch, is a 7500/9375-kva, 3-phase transformer supplying auxiliary power to the unit turbine and boiler. Surge protection equipment and potential transformers are housed in isolated phase cubicles near the generator. The generator neutral is grounded through a distribution transformer with secondary resistors.

The generator transformer is connected delta on the low and wye solidly grounded neutral on the high side and connects to a 69-kv bus in the switchyard. From this bus, three feeders extend to the transmission system and one to a 65,000/86,667-kva auto-transformer stepping up to a 138-kv bus. Two feeders tie into the 138-kv system. Both 69- and 138-kv buses are of the ring type, although the 138-kv ring will not be closed until the second generating unit is installed. Buses are of rigid construction supported from the ground on pedestal insulators. Lightning arresters are provided on the outgoing lines as well as the transformers.

The station auxiliary system consists of two parts; 2300 volts grounded neutral for all motors of 100 hp and larger, and 440 volts for smaller motors. Each 2300-volt bus is divided in two sections with half of the duplicate auxiliaries for the turbine and boiler on each bus. Each bus is provided with a normal source from the unit auxiliary transformer and a reserve source from a 7500/10,000-kva tertiary winding on the 69/138-kv bus tie transformer in the switchyard. Normally all auxiliary power will be served from the unit auxiliary transformer, but in event of failure of that supply, the buses are automatically transferred to the reserve.

The 460-volt system is likewise divided between two buses, each being supplied through a 750 kva, 3-phase dry type transformer. A tie is provided between the two bus sections and either transformer will carry the full load.

All auxiliary switchgear is of the conventional metal-clad type and is installed on the main floor in the aisle between boilers. Small motors are served from motor-control centers located at the station load centers.

Coal-handling facilities and cooling tower are supplied by feeders from the 2300-volt bus through an under-

ground duct system. Two such feeders, one a reserve, each connect through a 500-kva, 3-phase transformer to a motor control center in the coal breaker building, from which all motors in the coal-handling system are controlled. Two similar feeders extend to the cooling tower, where 500-kva transformers are installed to supply the tower fans. One of the transformers at the first tower is a reserve and will serve for all future towers.

Pumps located at the river and at the reservoir are also fed by services from the power station 2300-volt bus and controlled locally by outdoor metal-clad breakers at those locations.

Two 320-ampere-hour, 250-volt batteries are installed; one for electrical operation and one for emergency lighting, valve motors and emergency seal and turbine bearing oil pump motors.

Generator voltage is controlled by an amplidyne voltage regulator and a motor-driven reserved exciter, equipped with its own regulator, serves as an emergency excitation source.

All auxiliary power and control cable throughout the station is of the varnished cambric insulated steel armor type, laid in sheet metal trays. Control cables to the switchyard have rubber-like insulation and jacket. They are installed in large transite pipes underground to the switchyard to manholes from where they are laid directly in the earth to their terminals at the switchyard equipment.

Communication throughout the plant is furnished by an automatic telephone system with code call supplemented by a public address system.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| F.D. Fans | Buffalo Forge Co. | |
| I.D. Fans | Buffalo Forge Co. | |
| D.C. Heaters | Worthington Corp. | |
| Closed F.W. Heaters | Alco Prod. Div. American Locomotive Co. | |
| Turbine Room Crane | Whiting Corp. | 150 ton |
| Boiler Feed Pumps | Worthington Corp. | 600,000 lb per hr |
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| Cooling Tower | Marley Co. | |
| Water Treating | Permutit Co. | 1800 gpm |
| Demineralizing System | Permutit Co. | 50 gpm |
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| Condenser Tubes | Phelps Dodge Co. | |
| Steel Circ. Water Piping | American Boiler & Tank Co. | |
| Heater Drain Pump | Worthington Corp. | |
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| Bilge Pumps | Yeomans Brothers Co. | |
| Control Room Air-Conditioning Unit | Carrier Corp. | 20 ton |
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| Coal Dust Elimination Piping | Mellish & Murray Co. | |
| Heating & Ventilating Temperature Control | Johnson Service Co. | |
| Office Bldg. Mech. Refrigeration Compressor | Chrysler Airtemp Corp. | 60 ton |
| Level Alarm & Control Switches | Magnetrol, Inc. | |
| Alarm & Control Pressure Switches | Minneapolis-Honeywell Co. | |
| Coal-Handling Equipment | Link-Belt Co. | 300 tph initially |
| Ash Handling Equipment | United Conveyor Corp. | |
| Fire Pump | Fairbanks-Morse Co. | 500 gpm |
| Motors | Elliott Co. | |
| Control Panels | Westinghouse Elec. Corp. | |
| Amplidyne Voltage Regulators | General Elec. Co. | |
| Auxiliary Switchgear | Westinghouse Elec. Corp. | |
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| Auxiliary Power Transformers | Wagner Elec. Co. | |
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# A Survey of Some of the Thermodynamic and Physical Properties of Water

By E. J. WELLMAN* and W. L. SIBBITT†

Purdue University

**Following upon its publication in January of "The Present Status of Steam Properties" by F. G. Keyes and J. H. Keenan of Massachusetts Institute of Technology, COMBUSTION is privileged to present related information on liquid water properties compiled at Purdue University. For convenience of engineers working in this field, full-page tables giving values of specific heat, thermal conductivity, dynamic viscosity and Prandtl moduli have been included. Attention is called to the inclusion of accuracy values of the three measured properties and maximum errors of the Prandtl moduli.**

AN extensive research program is now in progress at Purdue University to determine the physical properties of fluids which are pertinent to their thermodynamic and heat transfer characteristics. Because of the importance of water as a power cycle fluid, a part of this program indicated the need for a careful compilation of the best values available for the properties of this fluid.

A survey was made of three of the properties of water. These three were, the constant pressure specific heat ($c_p$), the thermal conductivity ($k$), and the dynamic viscosity ($\mu$). These particular properties were selected because from them a fourth property may be calculated, namely the Prandtl modulus ($N_{Pr}$) which is defined as follows:

$$N_{Pr} = \frac{c_p \mu}{k}$$

Of the many dimensionless ratios used in heat transfer analysis the Prandtl modulus is unusual in that it is completely defined by the properties of the fluid and is therefore also a property. Hence values of the Prandtl Modulus may also be tabulated for various thermodynamic states of the fluid.

In the course of the survey it appeared that two types of information should be assembled. First, the most accurate values of the properties should be tabulated. Second, information as to the accuracy of these values should also be included. The term accuracy as used here is intended to represent the amount by which each value reported may differ from the true value. An immediate difficulty is apparent in that the true value may never be known. The accuracy values were therefore estimated by comparing values obtained by various investigators. From such comparisons, values obtained by one particular investigator were selected in each region such that this set of values resulted in the minimum differences from each of the other sets of values. The degree of accuracy was then determined by assuming that the true values would not differ from the tabulated values by an amount greater than that by which any of the reliably reported values differed from the tabulated values.

Unfortunately it was necessary to modify the above procedure in several instances because of the lack of sufficient data for comparison. These modifications will be apparent in the following discussion.

### *Maximum Errors*

Since the values finally tabulated for the Prandtl modulus were calculated from the other three properties, it is not readily possible to establish accuracy magnitudes. However, it may be demonstrated that the maximum error in the Prandtl modulus may be calculated (approximately) by taking the sum of the three accuracies of the three properties. Therefore the tabulation of Prandtl moduli includes values of maximum error. It must be noted that these numbers do not have the same significance as the accuracy values. The probable error in Prandtl moduli is undoubtedly of smaller magnitude in each case than the maximum error values tabulated.

In defining the limits of the pressure and temperature ranges to be considered it was desired to extend values to high pressure and temperature regions because of present-day interest in these values. Temperatures were therefore considered from 32 F (the melting point) to 690 F (about 15 degrees below the critical temperature). Pressures up to 6000 psia were included. The lack of extensive experimental values above this pressure made this limitation necessary.

### *Specific Heat Values*

In Table I are presented the specific heat values compiled. A large amount of experimental data was available for this property. However, only the values reported by Keenan and Keyes (1),[1] those of Koch (2), and those of Smith-Keyes (2), were sufficiently extensive to be of direct use over much of the range. The values tabulated are largely those of Koch. The saturation values are taken from Smith-Keyes (2) up to 500 F. The saturation values above 500 F are from Keenan and Keyes. The values for 5000 and 6000 psia are largely from

* Instructor in Mechanical Engineering.
† Professor of Mechnical Engineering.

[1] Numbers in parentheses refer to the Bibliography at the end of the paper.

**TABLE I**

**Constant Pressure Specific Heat of Liquid Water (t indicates temperature, degrees Fahrenheit) (a indicates accuracy, per cent); Unit of Specific Heat, B/lb$_m$F**

| | | | Pressure, psia, compressed liquid | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| t | Sat. Liquid | a | 1000 | a | 2000 | a | 3000 | a | 4000 | a | 5000 | a | 6000 | a |
| 32 | 4.340 | 0.5 | 4.309 | 0.6 | 4.279 | 0.6 | 4.248 | 0.6 | 4.218 | 0.6 | 4.187 | 1.0 | 4.157 | 1.0 |
| 40 | 3.742 | | 3.721 | | 3.699 | | 3.677 | | 3.656 | | 3.643 | | 3.613 | |
| 50 | 3.169 | | 3.154 | | 3.140 | | 3.126 | | 3.111 | | 3.097 | | 3.082 | |
| 60 | 2.731 | | 2.722 | | 2.714 | | 2.705 | | 2.696 | | 2.688 | | 2.679 | |
| 70 | 2.372 | | 2.369 | | 2.365 | | 2.361 | | 2.357 | | 2.354 | | 2.350 | |
| 80 | 2.084 | | 2.084 | | 2.083 | | 2.083 | | 2.082 | | 2.082 | | 2.081 | |
| 90 | 1.847 | | 1.848 | | 1.850 | | 1.851 | | 1.853 | | 1.854 | | 1.855 | |
| 100 | 1.650 | 0.7 | 1.654 | 0.8 | 1.658 | 0.8 | 1.663 | 0.8 | 1.667 | 0.8 | 1.671 | 1.0 | 1.675 | 1.0 |
| 110 | 1.487 | | 1.492 | | 1.498 | | 1.503 | | 1.509 | | 1.514 | | 1.519 | |
| 120 | 1.353 | | 1.360 | | 1.366 | | 1.373 | | 1.380 | | 1.387 | | 1.394 | |
| 130 | 1.236 | | 1.244 | | 1.252 | | 1.259 | | 1.267 | | 1.275 | | 1.283 | |
| 140 | 1.137 | | 1.145 | | 1.154 | | 1.162 | | 1.170 | | 1.179 | | 1.187 | |
| 150 | 1.050 | | 1.059 | | 1.068 | | 1.077 | | 1.086 | | 1.095 | | 1.103 | |
| 160 | .970 | | .979 | | .988 | | .997 | | 1.006 | | 1.015 | | 1.024 | |
| 170 | .902 | | .912 | | .921 | | .930 | | .939 | | .949 | | .958 | |
| 180 | .839 | | .849 | | .858 | | .868 | | .877 | | .887 | | .896 | |
| 190 | .786 | | .796 | | .806 | | .815 | | .825 | | .835 | | .845 | |
| 200 | .738 | 1.5 | .748 | 2.0 | .757 | 2.0 | .767 | 2.0 | .777 | 2.0 | .787 | 2.5 | .796 | 2.5 |
| 210 | .702 | | .711 | | .721 | | .731 | | .740 | | .750 | | .760 | |
| 212 | .687 | | .697 | | .706 | | .716 | | .726 | | .735 | | .745 | |
| 220 | .660 | | .670 | | .680 | | .689 | | .699 | | .709 | | .718 | |
| 230 | .624 | | .633 | | .643 | | .652 | | .661 | | .671 | | .680 | |
| 240 | .595 | | .604 | | .614 | | .623 | | .632 | | .641 | | .650 | |
| 250 | .568 | | .578 | | .587 | | .596 | | .605 | | .614 | | .624 | |
| 260 | .542 | | .551 | | .560 | | .569 | | .578 | | .587 | | .596 | |
| 270 | .515 | | .524 | | .533 | | .541 | | .550 | | .559 | | .567 | |
| 280 | .494 | | .502 | | .511 | | .519 | | .528 | | .538 | | .545 | |
| 290 | .472 | | .480 | | .488 | | .496 | | .505 | | .513 | | .521 | |
| 300 | .452 | 1.5 | .460 | 2.0 | .468 | 2.0 | .476 | 2.0 | .484 | 2.0 | .492 | 2.5 | .500 | 2.5 |
| 310 | .436 | | .442 | | .450 | | .459 | | .467 | | .475 | | .484 | |
| 320 | .420 | | .426 | | .433 | | .441 | | .449 | | .457 | | .464 | |
| 330 | .405 | | .411 | | .418 | | .426 | | .433 | | .440 | | .448 | |
| 340 | .391 | | .396 | | .404 | | .411 | | .418 | | .425 | | .432 | |
| 350 | .378 | | .384 | | .390 | | .396 | | .403 | | .407 | | .416 | |
| 360 | .366 | | .372 | | .378 | | .383 | | .390 | | .396 | | .401 | |
| 370 | .355 | | .361 | | .367 | | .372 | | .378 | | .384 | | .389 | |
| 380 | .346 | | .351 | | .356 | | .361 | | .366 | | .372 | | .377 | |
| 390 | .366 | | .340 | | .345 | | .350 | | .355 | | .360 | | .365 | |
| 400 | .327 | 3.0 | .330 | 3.5 | .335 | 3.5 | .340 | 3.5 | .345 | 3.5 | .350 | 4.0 | .355 | 4.0 |
| 410 | .318 | | .321 | | .326 | | .331 | | .336 | | .340 | | .346 | |
| 420 | .310 | | .312 | | .317 | | .322 | | .327 | | .331 | | .336 | |
| 430 | .302 | | .304 | | .309 | | .313 | | .318 | | .322 | | .327 | |
| 440 | .294 | | .296 | | .301 | | .305 | | .310 | | .314 | | .319 | |
| 450 | .287 | | .289 | | .293 | | .298 | | .302 | | .306 | | .310 | |
| 460 | .280 | | .282 | | .286 | | .290 | | .294 | | .298 | | .302 | |
| 470 | .274 | | .276 | | .280 | | .284 | | .287 | | .291 | | .295 | |
| 480 | .267 | | .270 | | .273 | | .277 | | .280 | | .284 | | .288 | |
| 490 | .262 | | .263 | | .267 | | .270 | | .274 | | .278 | | .281 | |
| 500 | .256 | 4.0 | .257 | 4.5 | .260 | 4.5 | .264 | 4.5 | .267 | 4.5 | .271 | 5.0 | .274 | 5.0 |
| 510 | .251 | | .251 | | .255 | | .258 | | .262 | | .266 | | .269 | |
| 520 | .246 | | .246 | | .249 | | .253 | | .256 | | .260 | | .264 | |
| 530 | .240 | 4.0 | .241 | 4.5 | .244 | 4.5 | .248 | 4.5 | .251 | 4.5 | .255 | 5.0 | .259 | 5.0 |
| 540 | .235 | | | | .239 | | .243 | | .247 | | .250 | | .254 | |
| 550 | .230 | | | | .235 | | .239 | | .243 | | .247 | | .250 | |
| 560 | .225 | | | | .231 | | .234 | | .238 | | .243 | | .246 | |
| 570 | .221 | | | | .226 | | .229 | | .234 | | .238 | | .242 | |
| 580 | .217 | | | | .222 | | .225 | | .230 | | .234 | | .239 | |
| 590 | .214 | | | | .217 | | .221 | | .226 | | .230 | | .235 | |
| 600 | .210 | 7.0 | | | .212 | 7.0 | .217 | 7.0 | .222 | 7.0 | .227 | 8.0 | .233 | 8.0 |
| 610 | .205 | | | | .207 | | .212 | | .218 | | .224 | | .230 | |
| 620 | .200 | 7.0 | | | .202 | 7.0 | .208 | 7.0 | .214 | 7.0 | .220 | 8.0 | .226 | 8.0 |
| 630 | .195 | | | | | | .202 | | .209 | | .216 | | .222 | |
| 640 | .190 | | | | | | .196 | | .203 | | .211 | | .218 | |
| 650 | .183 | | | | | | .189 | | .197 | | .206 | | .215 | |
| 660 | .177 | | | | | | .182 | | .192 | | .202 | | .212 | |
| 670 | .169 | | | | | | .174 | | .186 | | .198 | | .210 | |
| 680 | .161 | | | | | | .166 | | .180 | | .194 | | .208 | |
| 690 | .148 | 7.0 | | | | | | | .172 | 7.0 | .188 | 8.0 | .203 | 8.0 |

## TABLE II

**Thermal Conductivity of Liquid Water (t indicates temperature, degrees Fahrenheit) (a indicates accuracy, per cent); Unit of Thermal Conductivity, B/hr ft F**

| | | | Pressure, psia, Compressed Liquid | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| t | Sat. Liquid | a | 1000 | a | 2000 | a | 3000 | a | 4000 | a | 5000 | a | 6000 | a |
| 32 | 1.0083 | 0.3 | 1.0032 | 0.3 | 1.0004 | 0.5 | .9979 | 0.8 | .9948 | 1.1 | .992 | 1.5 | .989 | 1.5 |
| 40 | 1.0048 | | 1.0014 | | .9986 | | .9959 | | .9926 | | .991 | | .988 | |
| 50 | 1.0004 | | .9991 | | .9963 | | .9933 | | .9899 | | .987 | | .984 | |
| 60 | .9990 | | .9968 | | .9939 | | .9907 | | .9872 | | .984 | | .981 | |
| 70 | .9980 | | .9949 | | .9920 | | .9886 | | .9848 | | .982 | | .979 | |
| 80 | .9975 | | .9943 | | .9912 | | .9878 | | .9840 | | .981 | | .978 | |
| 90 | .9974 | | .9938 | | .9904 | | .9871 | | .9832 | | .980 | | .977 | |
| 100 | .9976 | 0.2 | .9932 | 0.2 | .9897 | 0.4 | .9864 | 0.8 | .9824 | 0.6 | .978 | 1.5 | .975 | 1.5 |
| 110 | .9976 | | .9932 | | .9895 | | .9860 | | .9819 | | .978 | | .974 | |
| 120 | .9977 | | .9934 | | .9895 | | .9858 | | .9817 | | .978 | | .974 | |
| 130 | .9981 | | .9937 | | .9896 | | .9856 | | .9814 | | .977 | | .973 | |
| 140 | .9988 | | .9940 | | .9897 | | .9854 | | .9811 | | .977 | | .973 | |
| 150 | .9996 | | .9950 | | .9905 | | .9861 | | .9817 | | .978 | | .974 | |
| 160 | 1.0004 | | .9959 | | .9913 | | .9868 | | .9823 | | .978 | | .974 | |
| 170 | 1.0012 | | .9969 | | .9921 | | .9876 | | .9829 | | .978 | | .974 | |
| 180 | 1.0022 | | .9980 | | .9931 | | .9885 | | .9836 | | .979 | | .975 | |
| 190 | 1.0034 | | .9984 | | .9945 | | .9896 | | .9847 | | .980 | | .975 | |
| 200 | 1.0047 | 0.2 | 1.0008 | 0.2 | .9958 | 0.4 | .9907 | 0.8 | .9857 | 0.6 | .981 | 1.5 | .976 | 1.5 |
| 210 | 1.0061 | | 1.0021 | | .9971 | | .9919 | | .9868 | | .982 | | .977 | |
| 212 | 1.0064 | | 1.0024 | | .9974 | | .9921 | | .9870 | | .982 | | .977 | |
| 220 | 1.0079 | | 1.0039 | | .9988 | | .9934 | | .9881 | | .983 | | .978 | |
| 230 | 1.0097 | | 1.0057 | | 1.0005 | | .9951 | | .9896 | | .985 | | .980 | |
| 240 | 1.0119 | | 1.0075 | | 1.0023 | | .9967 | | .9910 | | .986 | | .981 | |
| 250 | 1.0142 | | 1.0095 | | 1.0041 | | .9984 | | .9925 | | .988 | | .983 | |
| 260 | 1.0165 | | 1.0117 | | 1.0061 | | 1.0003 | | .9943 | | .989 | | .984 | |
| 270 | 1.0191 | | 1.0140 | | 1.0082 | | 1.0023 | | .9961 | | .991 | | .986 | |
| 280 | 1.0222 | | 1.0163 | | 1.0102 | | 1.0042 | | .9979 | | .993 | | .988 | |
| 290 | 1.0255 | | 1.0194 | | 1.0131 | | 1.0069 | | 1.0005 | | .995 | | .989 | |
| 300 | 1.0289 | 0.3 | 1.0232 | 0.3 | 1.0166 | 0.5 | 1.0101 | 0.9 | 1.0037 | 0.9 | .998 | 1.5 | .992 | 1.5 |
| 310 | 1.0322 | | 1.0270 | | 1.0200 | | 1.0132 | | 1.0068 | | 1.001 | | .995 | |
| 320 | 1.0354 | | 1.0307 | | 1.0235 | | 1.0164 | | 1.010 | | 1.004 | | .998 | |
| 330 | 1.0404 | | 1.0353 | | 1.0278 | | 1.0205 | | 1.014 | | 1.008 | | 1.002 | |
| 340 | 1.0455 | | 1.0399 | | 1.0322 | | 1.0246 | | 1.017 | | 1.011 | | 1.005 | |
| 350 | 1.0511 | | 1.0455 | | 1.0365 | | 1.0287 | | 1.021 | | 1.014 | | 1.008 | |
| 360 | 1.0564 | | 1.0496 | | 1.0411 | | 1.0331 | | 1.025 | | 1.018 | | 1.012 | |
| 370 | 1.0614 | | 1.0553 | | 1.0461 | | 1.0377 | | 1.029 | | 1.021 | | 1.014 | |
| 380 | 1.0669 | | 1.0611 | | 1.0510 | | 1.0424 | | 1.034 | | 1.026 | | 1.019 | |
| 390 | 1.0728 | | 1.0668 | | 1.0560 | | 1.0471 | | 1.038 | | 1.030 | | 1.022 | |
| 400 | 1.0794 | 0.3 | 1.074 | 0.3 | 1.062 | 0.5 | 1.053 | 0.9 | 1.043 | 0.9 | 1.035 | 1.5 | 1.027 | 1.5 |
| 410 | 1.0861 | | 1.080 | | 1.068 | | 1.059 | | 1.048 | | 1.040 | | 1.032 | |
| 420 | 1.0941 | | 1.087 | | 1.075 | | 1.065 | | 1.053 | | 1.045 | | 1.037 | |
| 430 | 1.1023 | | 1.095 | | 1.082 | | 1.072 | | 1.059 | | 1.051 | | 1.043 | |
| 440 | 1.1114 | | 1.105 | | 1.091 | | 1.079 | | 1.066 | | 1.057 | | 1.048 | |
| 450 | 1.1212 | | 1.114 | | 1.100 | | 1.087 | | 1.074 | | 1.065 | | 1.056 | |
| 460 | 1.1319 | | 1.124 | | 1.109 | | 1.095 | | 1.081 | | 1.071 | | 1.061 | |
| 470 | 1.1431 | | 1.136 | | 1.120 | | 1.104 | | 1.090 | | 1.079 | | 1.068 | |
| 480 | 1.1545 | | 1.149 | | 1.131 | | 1.114 | | 1.099 | | 1.087 | | 1.075 | |
| 490 | 1.1698 | | 1.163 | | 1.143 | | 1.125 | | 1.109 | | 1.095 | | 1.082 | |
| 500 | 1.1861 | 1.0 | 1.176 | 1.0 | 1.154 | 0.7 | 1.135 | 1.0 | 1.118 | 0.5 | 1.102 | 1.5 | 1.088 | 1.5 |
| 510 | 1.21 | | 1.19 | | 1.171 | | 1.151 | | 1.132 | | 1.115 | | 1.100 | |
| 520 | 1.23 | | 1.21 | | 1.188 | | 1.166 | | 1.146 | | 1.127 | | 1.110 | |
| 530 | 1.25 | 1.5 | 1.23 | 1.5 | 1.205 | 0.7 | 1.182 | 1.0 | 1.160 | 0.5 | 1.139 | 1.5 | 1.121 | 1.5 |
| 540 | 1.28 | | | | 1.225 | | 1.199 | | 1.175 | | 1.152 | | 1.132 | |
| 550 | 1.31 | | | | 1.252 | | 1.218 | | 1.192 | | 1.168 | | 1.147 | |
| 560 | 1.34 | | | | 1.278 | | 1.238 | | 1.209 | | 1.182 | | 1.158 | |
| 570 | 1.37 | | | | 1.304 | | 1.257 | | 1.227 | | 1.198 | | 1.172 | |
| 580 | 1.41 | | | | 1.341 | | 1.283 | | 1.246 | | 1.216 | | 1.189 | |
| 590 | 1.46 | | | | 1.382 | | 1.310 | | 1.265 | | 1.230 | | 1.200 | |
| 600 | 1.51 | 1.5 | | | 1.448 | 1.5 | 1.346 | 1.0 | 1.290 | 0.5 | 1.25 | 1.5 | 1.21 | 1.5 |
| 610 | 1.58 | | | | 1.52 | | 1.385 | | 1.317 | | 1.27 | | 1.23 | |
| 620 | 1.65 | 3.5 | | | 1.62 | 3.5 | 1.441 | 3.5 | 1.352 | 0.5 | 1.29 | 1.5 | 1.25 | 1.5 |
| 630 | 1.71 | | | | | | 1.509 | | 1.392 | | 1.32 | | 1.27 | |
| 640 | 1.88 | | | | | | 1.597 | | 1.442 | | 1.36 | | 1.31 | |
| 650 | 2.09 | | | | | | 1.701 | | 1.505 | | 1.40 | | 1.34 | |
| 660 | 2.34 | 4.0 | | | | | 1.817 | 4.0 | 1.576 | 0.5 | 1.43 | 1.5 | 1.36 | 1.5 |
| 670 | 2.84 | | | | | | 2.14 | | | | | | | |
| 680 | 3.5 | | | | | | 2.56 | | | | | | | |
| 690 | 5.5 | 5.0 | | | | | | | | | | | | |

## TABLE III

**Dynamic Viscosity of Liquid Water (t indicates temperature, degrees Fahrenheit) (a indicates accuracy, per cent); Unit of Viscosity, $lb_m/ft\ hr$**

| t | Sat. Liquid | a | Pressure, psia, Compressed Liquid 1000 | a | 2000 | a | 3000 | a | 4000 | a | 5000 | a | 6000 | a |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 13.74 | 1.5 | 13.52 | 1.9 | 13.33 | 2.1 | 13.14 | 2.4 | 12.93 | 2.7 | 12.72 | 3.5 | 12.51 | 3.7 |
| 40 | 11.59 | | 11.43 | | 11.28 | | 11.12 | | 10.95 | | 10.80 | | 10.63 | |
| 50 | 9.55 | | 9.44 | | 9.32 | | 9.19 | | 9.06 | | 8.93 | | 8.80 | |
| 60 | 8.03 | | 7.95 | | 7.86 | | 7.76 | | 7.66 | | 7.56 | | 7.47 | |
| 70 | 6.82 | | 6.76 | | 6.69 | | 6.61 | | 6.54 | | 6.46 | | 6.38 | |
| 80 | 5.89 | | 5.86 | | 5.78 | | 5.73 | | 5.67 | | 5.61 | | 5.55 | |
| 90 | 5.13 | | 5.09 | | 5.05 | | 5.01 | | 4.96 | | 4.91 | | 4.87 | |
| 100 | 4.52 | 1.6 | 4.49 | 2.0 | 4.46 | 2.2 | 4.43 | 2.6 | 4.39 | 2.4 | 4.36 | 3.5 | 4.32 | 3.7 |
| 110 | 4.02 | | 4.00 | | 3.98 | | 3.94 | | 3.93 | | 3.90 | | 3.87 | |
| 120 | 3.61 | | 3.60 | | 3.59 | | 3.57 | | 3.55 | | 3.53 | | 3.52 | |
| 130 | 3.27 | | 3.26 | | 3.25 | | 3.24 | | 3.23 | | 3.21 | | 3.20 | |
| 140 | 2.98 | | 2.97 | | 2.97 | | 2.96 | | 2.95 | | 2.94 | | 2.93 | |
| 150 | 2.74 | | 2.73 | | 2.73 | | 2.72 | | 2.72 | | 2.71 | | 2.71 | |
| 160 | 2.51 | | 2.51 | | 2.51 | | 2.51 | | 2.50 | | 2.50 | | 2.49 | |
| 170 | 2.33 | | 2.33 | | 2.33 | | 2.33 | | 2.33 | | 2.32 | | 2.32 | |
| 180 | 2.15 | | 2.16 | | 2.16 | | 2.16 | | 2.16 | | 2.16 | | 2.16 | |
| 190 | 2.01 | | 2.02 | | 2.02 | | 2.02 | | 2.03 | | 2.03 | | 2.03 | |
| 200 | 1.88 | 2.3 | 1.89 | 3.2 | 1.89 | 3.4 | 1.90 | 3.8 | 1.90 | 3.6 | 1.90 | 5.0 | 1.91 | 5.2 |
| 210 | 1.79 | | 1.80 | | 1.80 | | 1.80 | | 1.81 | | 1.81 | | 1.82 | |
| 212 | 1.73 | | 1.76 | | 1.76 | | 1.77 | | 1.77 | | 1.77 | | 1.78 | |
| 220 | 1.69 | | 1.69 | | 1.70 | | 1.70 | | 1.70 | | 1.71 | | 1.71 | |
| 230 | 1.59 | | 1.60 | | 1.60 | | 1.61 | | 1.61 | | 1.61 | | 1.62 | |
| 240 | 1.52 | | 1.53 | | 1.53 | | 1.54 | | 1.54 | | 1.54 | | 1.55 | |
| 250 | 1.45 | | 1.46 | | 1.47 | | 1.47 | | 1.47 | | 1.48 | | 1.48 | |
| 260 | 1.39 | | 1.40 | | 1.40 | | 1.41 | | 1.41 | | 1.41 | | 1.42 | |
| 270 | 1.33 | | 1.33 | | 1.34 | | 1.34 | | 1.34 | | 1.35 | | 1.35 | |
| 280 | 1.27 | | 1.28 | | 1.28 | | 1.29 | | 1.29 | | 1.30 | | 1.30 | |
| 290 | 1.22 | | 1.23 | | 1.23 | | 1.24 | | 1.24 | | 1.24 | | 1.24 | |
| 300 | 1.18 | 2.5 | 1.18 | 3.3 | 1.19 | 3.5 | 1.19 | 3.9 | 1.19 | 3.9 | 1.19 | 5.0 | 1.20 | 5.2 |
| 310 | 1.14 | | 1.14 | | 1.15 | | 1.15 | | 1.16 | | 1.16 | | 1.16 | |
| 320 | 1.10 | | 1.11 | | 1.11 | | 1.11 | | 1.12 | | 1.12 | | 1.12 | |
| 330 | 1.07 | | 1.07 | | 1.08 | | 1.08 | | 1.08 | | 1.09 | | 1.09 | |
| 340 | 1.04 | | 1.04 | | 1.05 | | 1.05 | | 1.05 | | 1.05 | | 1.06 | |
| 350 | 1.02 | | 1.02 | | 1.02 | | 1.02 | | 1.02 | | 1.01 | | 1.02 | |
| 360 | 0.993 | | 0.997 | | 0.996 | | 0.993 | | 0.994 | | 0.994 | | 0.991 | |
| 370 | .973 | | .977 | | .975 | | .972 | | .971 | | .968 | | .965 | |
| 380 | .956 | | .958 | | .954 | | .952 | | .949 | | .946 | | .942 | |
| 390 | .941 | | .939 | | .934 | | .930 | | .926 | | .922 | | .917 | |
| 400 | .927 | 5.0 | .924 | 5.8 | .918 | 6.0 | .914 | 6.4 | .908 | 6.4 | .905 | 7.5 | .902 | 8.0 |
| 410 | .913 | | .909 | | .903 | | .898 | | .892 | | .889 | | .887 | |
| 420 | .903 | | .897 | | .890 | | .884 | | .877 | | .874 | | .872 | |
| 430 | .894 | | .886 | | .877 | | .872 | | .864 | | .861 | | .858 | |
| 440 | .886 | | .878 | | .869 | | .862 | | .854 | | .850 | | .846 | |
| 450 | .876 | | .871 | | .861 | | .854 | | .845 | | .841 | | .836 | |
| 460 | .871 | | .866 | | .855 | | .845 | | .835 | | .829 | | .822 | |
| 470 | .867 | | .863 | | .852 | | .840 | | .829 | | .822 | | .813 | |
| 480 | .863 | | .861 | | .849 | | .836 | | .824 | | .816 | | .807 | |
| 490 | .865 | | .862 | | .847 | | .833 | | .821 | | .812 | | .802 | |
| 500 | .87 | 9.5 | .86 | 10.5 | .84 | 10.2 | .83 | 10.5 | .82 | 10.0 | .81 | 11.5 | .80 | 11.5 |
| 510 | .88 | | .86 | | .85 | | .83 | | .82 | | .80 | | .79 | |
| 520 | .89 | | .87 | | .85 | | .83 | | .82 | | .80 | | .79 | |
| 530 | .90 | 10.0 | .88 | 11.0 | .86 | 10.2 | .84 | 10.5 | .82 | 10.0 | .81 | 11.5 | .79 | 11.5 |
| 540 | .90 | | | | .87 | | .85 | | .83 | | .81 | | .80 | |
| 550 | .93 | | | | .89 | | .86 | | .84 | | .82 | | .80 | |
| 560 | .95 | | | | .90 | | .87 | | .85 | | .83 | | .81 | |
| 570 | .97 | | | | .92 | | .88 | | .86 | | .84 | | .82 | |
| 580 | 1.00 | | | | .95 | | .90 | | .87 | | .85 | | .83 | |
| 590 | 1.04 | | | | .98 | | .92 | | .89 | | .86 | | .84 | |
| 600 | 1.09 | 13.5 | | | 1.02 | 13.5 | .95 | 13.0 | .91 | 12.5 | .88 | 14.5 | .85 | 14.5 |
| 610 | 1.14 | | | | 1.09 | | 1.00 | | .93 | | .90 | | .87 | |
| 620 | 1.20 | 15.5 | | | 1.18 | 15.5 | 1.03 | 15.5 | .96 | 12.5 | .92 | 14.5 | .88 | 14.5 |
| 630 | 1.25 | | | | | | 1.09 | | 1.00 | | .94 | | .90 | |
| 640 | 1.39 | | | | | | 1.16 | | 1.03 | | .97 | | .93 | |
| 650 | 1.56 | | | | | | 1.24 | | 1.09 | | 1.01 | | .96 | |
| 660 | 1.77 | 16.0 | | | | | 1.34 | 16.0 | 1.15 | 12.5 | 1.04 | 14.5 | .99 | 14.5 |
| 670 | 2.19 | | | | | | 1.61 | | | | | | | |
| 680 | 2.75 | | | | | | 1.97 | | | | | | | |
| 690 | 4.40 | 17.0 | | | | | | | | | | | | |

## TABLE IV

Prandt Moduli for Liquid Water (t indicates temperature, degrees Fahrenheit) (e indicates maximum error, %

| t | Sat. Liquid | e | Pressure, psia, Compressed Liquid | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1000 | e | 2000 | e | 3000 | e | 4000 | e | 5000 | e | 6000 | e |
| 32 | 0.3185 | 0.7 | 0.3198 | 1.0 | 0.3211 | 1.0 | 0.3227 | 1.0 | 0.3246 | 1.0 | 0.3266 | 1.0 | 0.3286 | 1.2 |
| 40 | .3245 | | .3260 | | .3275 | | .3294 | | .3314 | | .3335 | | .3358 | |
| 50 | .3319 | | .3337 | | .3356 | | .3377 | | .3398 | | .3422 | | .3447 | |
| 60 | .3397 | | .3414 | | .3433 | | .3454 | | .3476 | | .3500 | | .3528 | |
| 70 | .3472 | | .3487 | | .3508 | | .3530 | | .3551 | | .3576 | | .3604 | |
| 80 | .3532 | | .3537 | | .3570 | | .3590 | | .3616 | | .3640 | | .3665 | |
| 90 | .3589 | | .3608 | | .3629 | | .3651 | | .3676 | | .3700 | | .3723 | |
| 100 | .3641 | 0.7 | .3659 | 1.0 | .3680 | 1.0 | .3703 | 1.0 | .3727 | 1.0 | .3751 | 1.0 | .3777 | 1.2 |
| 110 | .3689 | | .3707 | | .3727 | | .3760 | | .3773 | | .3797 | | .3822 | |
| 120 | .3733 | | .3751 | | .3771 | | .3792 | | .3815 | | .3839 | | .3862 | |
| 130 | .3772 | | .3790 | | .3810 | | .3831 | | .3853 | | .3877 | | .3900 | |
| 140 | .3810 | | .3828 | | .3847 | | .3868 | | .3891 | | .3914 | | .3938 | |
| 150 | .3836 | | .3855 | | .3875 | | .3897 | | .3920 | | .3944 | | .3968 | |
| 160 | .3861 | | .3880 | | .3902 | | .3924 | | .3948 | | .3973 | | .3997 | |
| 170 | .3884 | | .3903 | | .3925 | | .3947 | | .3971 | | .3996 | | .4020 | |
| 180 | .3905 | | .3924 | | .3945 | | .3968 | | .3992 | | .4017 | | .4041 | |
| 190 | .3923 | | .3942 | | .3964 | | .3986 | | .4010 | | .4034 | | .4059 | |
| 200 | .3935 | 0.6 | .3957 | 1.0 | .3980 | 1.0 | .4003 | 1.0 | .4027 | 1.0 | .4051 | 1.0 | .4074 | 1.2 |
| 210 | .3943 | | .3970 | | .3995 | | .4017 | | .4044 | | .4067 | | .4088 | |
| 212 | .3944 | | .3972 | | .3998 | | .4020 | | .4047 | | .4070 | | .4091 | |
| 220 | .3950 | | .3977 | | .4003 | | .4028 | | .4055 | | .4079 | | .4103 | |
| 230 | .3957 | | .3983 | | .4010 | | .4037 | | .4064 | | .4091 | | .4118 | |
| 240 | .3961 | | .3988 | | .4016 | | .4043 | | .4071 | | .4099 | | .4127 | |
| 250 | .3964 | | .3992 | | .4021 | | .4048 | | .4077 | | .4106 | | .4135 | |
| 260 | .3964 | | .3992 | | .4021 | | .4048 | | .4077 | | .4106 | | .4135 | |
| 270 | .3962 | | .3991 | | .4020 | | .4048 | | .4078 | | .4107 | | .4136 | |
| 280 | .3959 | | .3987 | | .4018 | | .4048 | | .4079 | | .4109 | | .4140 | |
| 290 | .3955 | | .3984 | | .4015 | | .4047 | | .4078 | | .4110 | | .4141 | |
| 300 | .3952 | 0.7 | .3981 | 1.0 | .4013 | 1.0 | .4045 | 1.0 | .4076 | 1.0 | .4109 | 1.0 | .4141 | 1.2 |
| 310 | .3948 | | .3975 | | .4006 | | .4038 | | .4069 | | .4102 | | .4137 | |
| 320 | .3944 | | .3969 | | .3998 | | .4029 | | .4060 | | .4094 | | .4131 | |
| 330 | .3933 | | .3958 | | .3988 | | .4019 | | .4050 | | .4084 | | .4122 | |
| 340 | .3921 | | .3947 | | .3977 | | .4009 | | .4040 | | .4075 | | .4114 | |
| 350 | .3906 | | .3933 | | .3965 | | .3997 | | .4031 | | .4069 | | .4108 | |
| 360 | .3891 | | .3919 | | .3951 | | .3984 | | .4020 | | .4059 | | .4101 | |
| 370 | .3876 | | .3904 | | .3936 | | .3970 | | .4006 | | .4046 | | .4089 | |
| 380 | .3857 | | .3885 | | .3919 | | .3954 | | .3991 | | .4031 | | .4077 | |
| 390 | .3834 | | .3863 | | .3900 | | .3937 | | .3975 | | .4017 | | .4063 | |
| 400 | .3809 | 1.7 | .3840 | 2.0 | .3880 | 2.0 | .3920 | 2.0 | .3960 | 2.0 | .4000 | 2.0 | .4043 | 2.5 |
| 410 | .3783 | | .3817 | | .3860 | | .3903 | | .3944 | | .3983 | | .4021 | |
| 420 | .3753 | | .3787 | | .3833 | | .3877 | | .3920 | | .3960 | | .3999 | |
| 430 | .3724 | | .3757 | | .3806 | | .3850 | | .3894 | | .3936 | | .3976 | |
| 440 | .3693 | | .3728 | | .3776 | | .3821 | | .3865 | | .3907 | | .3947 | |
| 450 | .3670 | | .3697 | | .3745 | | .3791 | | .3836 | | .3880 | | .3922 | |
| 460 | .3640 | | .3664 | | .3713 | | .3761 | | .3809 | | .3857 | | .3904 | |
| 470 | .3608 | | .3630 | | .3678 | | .3727 | | .3775 | | .3823 | | .3872 | |
| 480 | .3575 | | .3595 | | .3642 | | .3689 | | .3738 | | .3784 | | .3832 | |
| 490 | .3535 | | .3553 | | .3603 | | .3650 | | .3698 | | .3744 | | .3791 | |
| 500 | .3494 | 4.5 | .3510 | 5.0 | .3562 | 5.0 | .3611 | 5.0 | .3658 | 5.0 | .3705 | 5.0 | .3750 | 5.0 |
| 510 | .3446 | | .3461 | | .3519 | | .3574 | | .3626 | | .3677 | | .3725 | |
| 520 | .3397 | | .3410 | | .3475 | | .3535 | | .3591 | | .3645 | | .3697 | |
| 530 | .3348 | 4.5 | .3356 | 5.0 | .3424 | 5.0 | .3486 | 5.0 | .3545 | 5.0 | .3602 | 5.0 | .3657 | 5.0 |
| 540 | .3298 | | | | .3371 | | .3437 | | .3499 | | .3559 | | .3617 | |
| 550 | .3246 | | | | .3318 | | .3386 | | .3452 | | .3515 | | .3577 | |
| 560 | .3189 | | | | .3256 | | .3328 | | .3398 | | .3465 | | .3530 | |
| 570 | .3130 | | | | .3190 | | .3265 | | .3339 | | .3410 | | .3478 | |
| 580 | .3064 | | | | .3118 | | .3198 | | .3277 | | .3354 | | .3429 | |
| 590 | .2997 | | | | .3045 | | .3130 | | .3215 | | .3298 | | .3380 | |
| 600 | .2919 | 5.0 | | | .2962 | 5.0 | .3056 | 5.0 | .3146 | 5.0 | .3232 | 5.0 | .3318 | 5.0 |
| 610 | .2839 | | | | .2875 | | .2979 | | .3074 | | .3167 | | .3257 | |
| 620 | .2753 | | | | .2778 | | .2892 | | .2997 | | .3100 | | .3199 | |
| 630 | .2662 | | | | | | .2800 | | .2916 | | .3030 | | .3137 | |
| 640 | .2565 | | | | | | .2700 | | .2831 | | .2953 | | .3068 | |
| 650 | .2454 | | | | | | .2588 | | .2736 | | .2869 | | .2993 | |
| 660 | .2335 | | | | | | .2469 | | .2634 | | .2779 | | .2914 | |
| 670 | .2198 | | | | | | .2319 | | .2516 | | .2679 | | .2830 | |
| 680 | .2056 | | | | | | .2161 | | .2395 | | .2577 | | .2744 | |
| 690 | .1854 | 5.0 | | | | | | | .2242 | 5.0 | .2463 | 5.0 | .2661 | 5.0 |

Keenan and Keyes but partially modified to maintain consistency with extrapolations of the Koch data.

The values in the table indicate fairly high accuracy for specific heat values particularly at the lower temperatures. The fact that the saturation values increase very rapidly as the critical temperature is approached leads to much lower accuracy in this vicinity.

### *Thermal Conductivity Value*

The thermal conductivity values are listed in Table II. These values are based primarily on the work of Schmidt and Sellschopp (3) in 1932 and Timroth and Vargaftik (4) in 1940. These investigations established the previously unrecognized fact that the thermal conductivity increases with temperature to a maximum at about 260 F and then decreases as the critical temperature is approached. The Schmidt-Sellschopp investigation did not yield values for the compressed liquid, hence these values are entirely from the Timroth-Vargaftik data. The difficulty experienced by several investigators in determining the effect of pressure upon thermal conductivity is an indirect confirmation of the small effect indicated by Timroth-Vargaftik.

The accuracy values listed demonstrate that there is greater uncertainty in the values of thermal conductivity than in those of specific heat.

### *Dynamic Viscosity Values*

Values of dynamic viscosity are given in Table III. A large amount of experimental data was examined for this property, but numerous difficulties were encountered since there appeared to be very large variations in the values reported for identical conditions. Also many of the investigations covered only a small portion of the temperature and pressure range desired.

It was found necessary to formulate values by subdividing the temperature range into three sections. For the saturated liquid from 32 F to 230 F the values given by Dorsey (2) were used. From 230 F to 302 F the values of Sigwart (2) were used. Above 302 F the saturation values are those obtained by Timroth (5). Since few of the investigators were able to establish extensive or consistent values for the pressure effect in the temperature range up to 320 F an "average" pressure effect curve was drawn using a large number of values reported by Dorsey and the pressure effect noted by Timroth for 302 F. This was used to establish the compressed liquid values up to 302 F. Above 302 F the compressed liquid values are from Timroth (5).

These methods were obviously of limited accuracy and this fact was considered in establishing the accuracy values shown in the table.

### *Prandtl Moduli Values*

Finally, Table IV was prepared by calculating each value from corresponding values in each of the above-mentioned tables. The values of the Prandtl moduli indicated no apparent inconsistencies. It may be noted that the Prandtl modulus for the saturated liquid decreases rapidly with increasing temperature until a minimum of 0.863 is reached at about 480 F. Values increase from this point, increasing rapidly as the critical temperature is approached. Another notable feature of the Prandtl modulus is the small effect of pressure over a large part of the temperature range. A negative pressure effect is noted up to 175 F, positive from 175 F to 360 F, and again negative above 360 F. In the range 120 F to 420 F the values at 6000 psia differ from the corresponding saturation values by less than three precent. Hence, due to the limited accuracy of all values the pressure effect in this range for most purposes is negligible.

It is hoped that the tables herein presented will be of value in heat transfer calculations. They present an assembled body of data which may avoid a tedious search for properties in a number of sources. The accuracy values also gives an indication of the confidence which may be placed in the values. These accuracy values are probably pessimistic so that future revisions will probably result in small changes in the values tabulated.

The Prandtl moduli may prove especially useful since the table presents a property of water which has not previously been presented in such detail.

The material in this paper is adapted from a Master's thesis.[1]

[1] "A Survey of the Thermodynamic and Physical Properties of Water," by E. J. Wellman, M.S. Thesis, Purdue University, January 1950.

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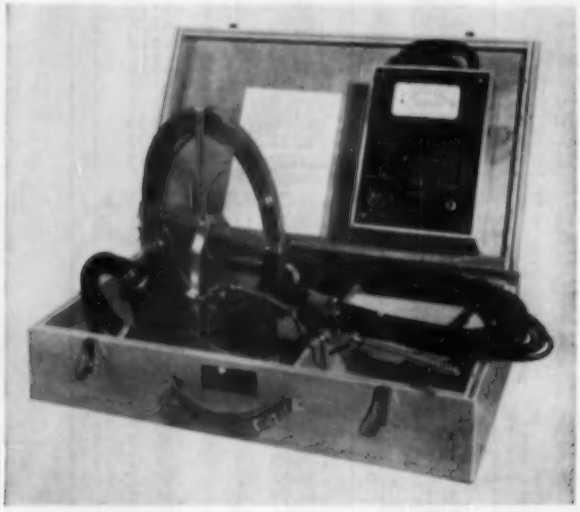

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# The Monotube Once-Through Boiler for Conventional or Supercritical Pressures*

By ARTHUR T. HUNTER

Vice President, Combustion Engineering, Inc.

**While European engineers have long been familiar with the Sulzer Monotube design for steam generating units, this American Power Conference paper is believed to be the first presentation showing specific adaptations of this type once-through boiler to American power plant practice. Emphasis is placed upon the versatility of the Monotube design and its potential usefulness in industrial power plants as well as central stations.**

RECENTLY, attention has been focused on the potentialities of the once-through boiler for power plants in the United States. This has come about primarily because of the use of this design for two large utility units operating above the critical pressure.

For years the trend in European practice has been in the direction of the once-through boiler at steam conditions corresponding to the most advanced used in the United States at the time. On this account, a large background of design and operating experience has accumulated and is now available to permit similar rapid advances in application of once-through boilers in this country.

One incentive to development along this line in Europe lay in the dual needs to (1) eliminate the heavy thick-walled boiler drums which were not readily available, and (2) to conserve scarce materials. During the past 20 years the extremely high cost of fuel and need for its conservation have justified the general European use of the more complex thermal cycles as well as high steam temperatures and pressures. Included among these power plant practices, and unusual with us in industrial work, are independent closed cycle high-pressure steam systems with complete condensate return using steam transformers for process steam generation, and also the rather general use of steam and gas reheat. The great flexibility inherent in the Monotube once-through design has been one of the factors leading to its adoption for these special conditions.

In our opinion, there are many reasons to believe that the once-through boiler will have wide application in the United States. It is particularly adapted to large utility installation with increasingly efficient cycles at higher steam pressures and temperatures and also to special cycles in industrial power generation. The demands for progress have brought the accepted thermal cycles to the point where the economic and technical advantages of this type of forced circulation are evident. Above critical pressure, it is the only system available which can be put to use.

### *European Background*

With this prospect in mind, Combustion Engineering, Inc., early in 1953 entered into a license and technical assistance agreement with Sulzer Brothers, Ltd., of Switzerland, covering the "Monotube Steam Generating Plant."

Of particular interest in the Sulzer Monotube background of 20 years, are the following case studies of actual installations.

Typical of the many Monotube units which have been in successful operation for over 2,000,000 service hours at 1500 to 2300 pounds pressure is that shown in Fig. 1. It is one of two tangentially fired units in a briquetting plant and has a steaming capacity of 200,000 lb/hr at 2150 psig, 935 F, with reheat to 752 F.

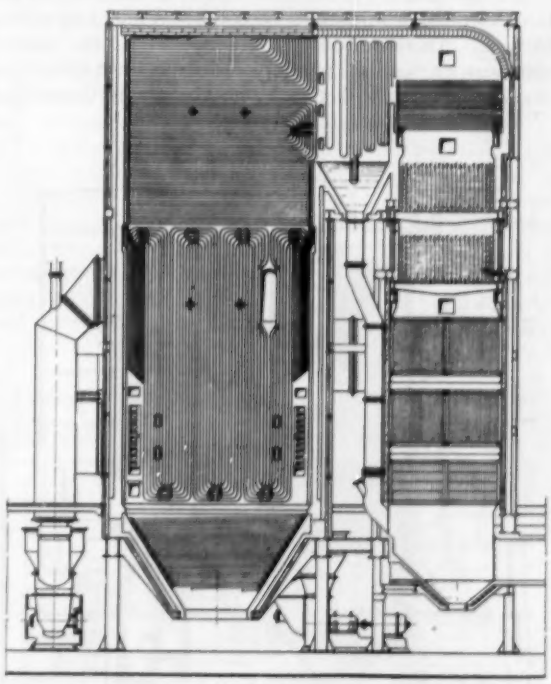


**Fig. 1—Cross-section of Sulzer Monotube Steam Generator having a capacity of 200,000 lb per hr at 2150 psig, 935 F, reheat to 752 F, installed in a European industrial power plant**

* Presented at American Power Conference, Chicago, Illinois, March 30, 1955.

On a recent European inspection trip, it was my privilege to visit this plant and obtain firsthand knowledge of the fifteen years outstanding performance of this equipment. It is of interest to note that this plant is direct firing pulverized brown coal having a lower heat value of only 3100 Btu per lb and a moisture content of 62 per cent.

Fig. 2 shows a cross-section through a Buckau-Sulzer Monotube Steam Generator having a capacity of 660,000 lb/hr, 1620 psig, 985 F installed in a new German central station. Two boilers of the same capacity are connected to a 150,000-kw condensing turbine. The design makes special provision for burning brown coal having the low heating value of 2800 Btu per lb and low ash softening temperature of 1750 F, as well as a high moisture content of 61 per cent. This is a mine-mouth plant with cooling towers for condenser water.

Attention is directed to the large economizer surface arranged in conventional manner at the rear of the unit, the Monotube circuits arranged vertically in the lower portion of the furnace and the upper side wall horizontal radiant superheater surface with pendant intermediate and finishing sections; also, the large evaporative platen surfaces in the upper portion of the furnace. This design with tangential pulverized coal firing is typical of the latest thinking in large Monotube Steam Generating Unit design and is directly applicable to American practice.

The solution to one of the difficult and unusual European fuel burning problems is shown in Fig. 3. This is a cross-section of a 407,000 lb/hr, Monotube Steam Generating unit, 2060 psig with primary steam temperature of 1015 F. Reheat to 1015 F temperature is obtained by the use of a combination flue gas and steam-heated reheater.

This installation is the first unit in a new Belgian station comprising initially a 60,000-kw condensing reheat turbine. As background for this design, the electric company can call on accumulated experience over a period of six years with two Monotube Steam Generating units, each serving a 50,000-kw turbine and burning similar mine-waste coal. This fuel has an ash content of 45 per cent, volatile as low as 10 per cent, and a low heating value of 7300 Btu per lb. To insure satisfactory combustion with this extremely low volatile coal, a furnace with a double U-shaped flame path was chosen.

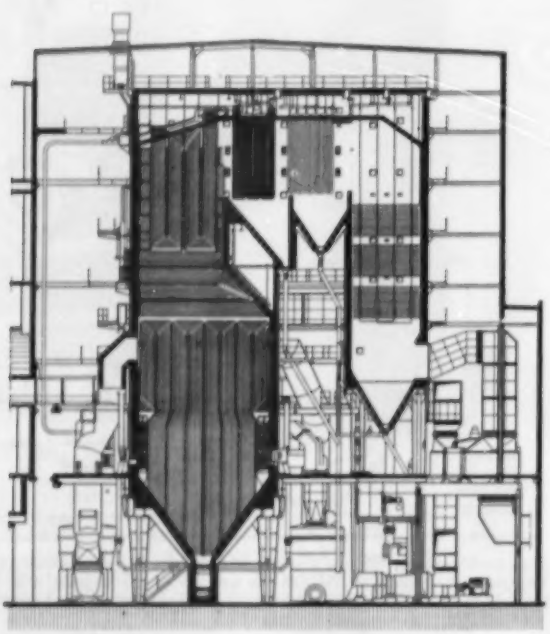
### *The Monotube System*

Shown here is a diagram, Fig. 4, illustrating the fundamental layout of the cycle of the Monotube steam plant and below it the temperature-entropy diagram with changes of state of the working medium. For the sake of simplicity, consider the cycle as a closed system.

Under normal conditions the feedwater leaving the starting vessel flows to the feed pump and reaches the steam generator by way of the pressure difference regulating valve and the feedwater regulator. In the Monotube unit the water first flows through the economizer and then goes directly to the evaporator section where all but a small part of the water is changed to steam. This mixture of steam and water passes to the separator where the residual water is removed. The latter is introduced to provide means of removing the solid impurities concentrated into a small quantity of water. The steam then passes through a flow metering device, which provides one of the impulses for the feedwater regulating valve. It returns to the steam generator entering the convection superheater and finally attaining the desired temperature in the radiant superheater. Steam at the proper temperature and pressure will then flow through the stop valve to the turbine.

The feedwater supply is automatically governed by a two-element regulating device. The primary impulse is taken from the steam flow, and the vernier impulse established by a thermostat, thus adapting the feedwater quantity to the heat input.

One or more thermostats, arranged along the superheater, regulate the final steam temperature by controlling the water injection. The automatic steam stop



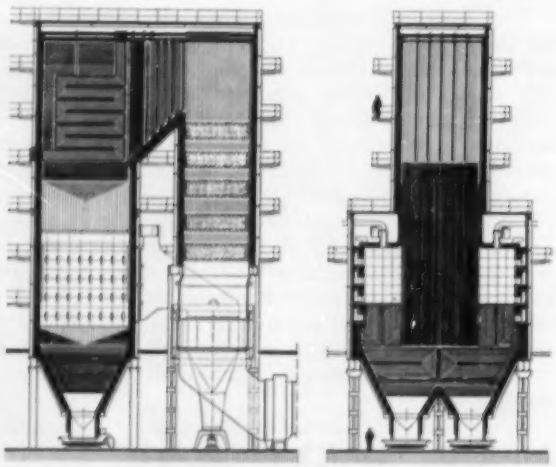


Fig. 3—Cross-section of Sulzer Monotube Steam Generator having a capacity of 407,000 lb per hr at 2060 psig, 1015 F with reheat to 1015 F, installed in a Belgian central station

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Fig. 2—Cross-section of Buckau-Sulzer Monotube Steam Generator having a capacity of 660,000 lb per hr at 1620 psig, 985 F, installed in a German central station

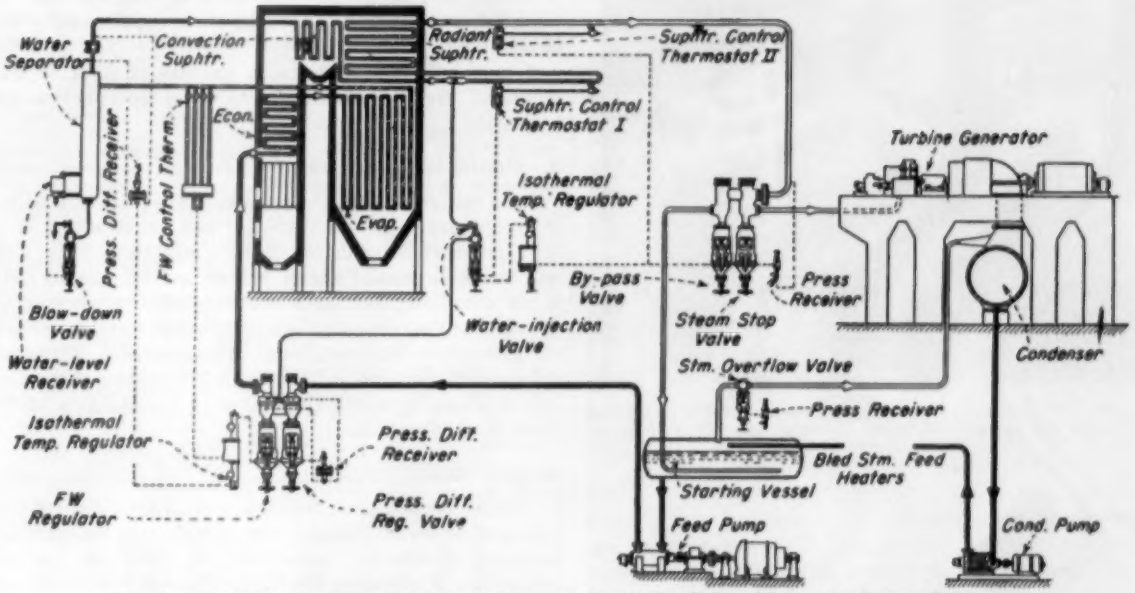


**Fig. 4—Schematic diagram showing fundamentals of the Sulzer Monotube Steam Generator**

valve, together with the bypass valve, serves as a safety device. These valves protect the turbine against abnormal steam temperatures and pressures. During the starting period, and under abnormal conditions, the steam stop valve closes automatically, and the steam or water and steam mixture is led through the automatic bypass valve to the starting vessel. With this arrangement any condensate loss is minimized and the whole tube system, especially the superheater, is protected during starting and other unstable periods by maintaining flow. When the entire quantity of steam cannot be condensed in the starting vessel, the excess steam is led through a steam relief valve to the main condenser.

The regulating valves and controls of the Monotube system have been developed as the result of years of research effort and operating experience. They are the heart of this system. Essentially hydraulic in character, their rugged simplicity combined with high speed of response, gives these controls the characteristics necessary to meet the exacting demands of American utility practice.

Stability of circulation and control of water distribution in the tube system are vital to the operation of any steam generating unit. The background of study and successful experience that has led up to the Monotube design provide a system which is inherently sound in this respect, satisfying the special requirements involved.

### *Philadelphia Electric Superpressure Unit*

As is well-known, the Monotube design is especially well adapted to supercritical pressure. On August 29, 1954, Mr. R. G. Rincliffe, president of Philadelphia Electric Company, announced "plans to construct a power generating station that will establish new highs for efficiency, steam pressure and temperature and unit size." This plant will employ the supercritical pressure cycle and incorporate a Monotube once-through steam generator designed for 6000 psig.

The cycle conditions selected call for 5000 psig at the turbine throttle and 1200 F primary steam temperature, with initial operation at 1150 F. There will be two stages of reheat to 1050 F. The boiler unit will have a primary steam flow of 1,540,000 lb per hour at 275,000 kw gross generation. Initial reheat will be at approximately 1050 psig and second reheat at approximately 250 psig. The overall arrangement of the unit with two separate furnaces follows the conventional pattern of the large controlled-circulation designs already being built in capacities up to 275,000 kw.

The twin pulverized coal furnaces will be designed for conventional heat release factors to permit furnace leaving temperatures in line with the requirements for burning low-ash fusion temperature Fairmont coals.

In the superpressure steam generator approximately 65 per cent of the total heat input will be taken up in superheating and reheating surface. This is contrasted with the 40 per cent absorbed in this surface in the typical cycle of 1800 psig, 1000/1000 F. In consequence, to obtain the desired low furnace leaving temperatures, relatively large radiant surfaces in superheater and reheater will be used. Heat-absorbing surface used for water

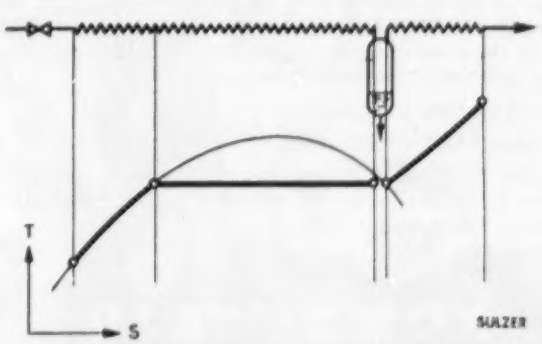


**Fig. 5—Temperature-entropy diagram for Fig. 4 pictures changes of state of the working medium during water heating, evaporating and superheating**

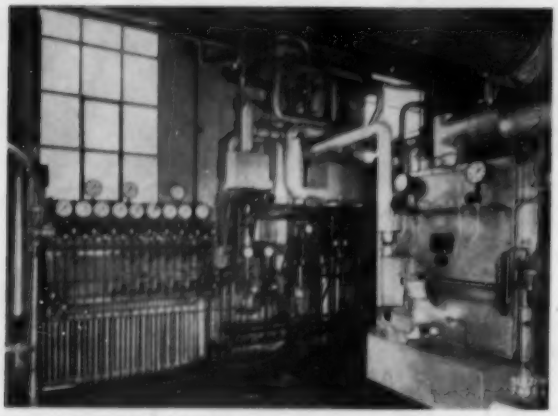

**Fig. 6—View showing Monotube Steam Generator operating above critical pressure in Sulzer thermal laboratory, Winterthur, Switzerland**

heating will be located in the bottom and burner areas subject to highest heat input. Upper portion of the furnaces will be entirely covered with radiant superheater or reheater surface, with the finishing primary steam temperature to 1200 F in conventional pendant convection surface located at each furnace outlet. One reheater will be located separately in each of the two furnaces. Thus, it is possible to obtain independent control of both reheat temperatures by burner tilt with vernier control of primary steam temperature by spray desuperheat.

The Monotube water heating surface will consist of the required number of tubes in parallel arranged in circuits up and down the furnace walls, with headers for inlet and outlet. This, in general, follows the well-established design practice successfully employed in sub-critical high-pressure Sulzer Monotube Boiler installations in Europe. As was indicated earlier, some 30 units operating between 1500–2300 psig, and at primary and reheat temperatures up to 1015 F have been in use from 10 to 15 years, with a successful service record of over two million hours.

As a logical development of the application of small diameter tubes (1-$^1/_2$" O.D.) in controlled-circulation boilers, these small tubes will be used in the superpressure Monotube unit, with the thickness required for 5000-psig service corresponding to that of large diameter tubes in established natural circulation practice at the 1400 to 1800-psig level.

It will be of interest to note that because of the reduction of steam volume with the increase in pressure, the weight of material required in the primary steam piping is of the same order of magnitude as would be required for 2400 psig at the same temperature.

### *Considerations for Superpressure Stations*

The principal considerations in the use of superpressure lie, in our judgment, outside the steam generating unit. These are as follows:

#### 1. Water Treatment

The use of standard demineralizing equipment will be provided to assure makeup water having a solids content under 0.1 ppm. This in a nominally closed cycle is considered suitable for use in the superpressure unit from the standpoint of possible tube or turbine blade deposits. It is recognized that oxygen removal of the highest order is essential, and deaeration to meet these requirements will be provided. Further elimination of oxygen and pH control may be obtained through the use of some of the standard organic additives such as morpholine or hydrazine.

#### 2. Condenser Leakage

It is recognized that condenser leakage is not to be tolerated and with care in design and construction it is anticipated that condenser leakage will be initially, and will remain, essentially zero. However, in the event that minor condenser leakage is encountered, it is planned to provide for the removal of the solids introduced by means of a bypass demineralizing arrangement. This demineralizer, capable of handling a substantial portion of the condensate, would then serve nominally as a blowdown for the system.

#### 3. Controls

The Monotube once-through system provides for circulation of water through the superheater on start-up insuring superheater protection. In addition, for the protection of reheaters, discharge of steam to a condenser injection cooler is arranged in the system, bypassing the turbine through the reheaters either on start or during emergency. This system calls for the use of automatic stop and bypass valves, and for feed and temperature control valves arranged to satisfy the requirements for steam and water quantities, pressures, and temperatures in normal and emergency operation. These functions are incorporated in the Sulzer control system. Extensive experience and background in design, construction and operation of these control systems in the European Sulzer installations furnish a solid foundation for handling the special considerations involved in this superpressure control system.

#### 4. Metallurgy for High Temperatures

The experience existing at temperatures up to 1100 F, and the later developments in alloy metallurgy for high temperature permit all concerned to approach the high temperature problems involved in this installation with complete confidence.

### *Superpressure Test Laboratory*

This photograph, Fig. 6, shows the elaborate superpressure test facilities in the Sulzer thermal laboratory. The steam generating unit shown on the right has been in operation above 4500 psig pressure at temperatures up to 1200 F since February 1954. The data obtained relative to water and steam quality and other characteristics of superpressure fluids are being incorporated in the design of the Philadelphia Electric Superpressure Unit. Results to date indicate that the superpressure problems in the large steam generating unit can be handled with safety and assurance.


### *Acknowledgment*

Acknowledgment is due to Dr. J. Gastpar, Vice President and Managing Director, Sulzer Brothers Ltd., Winterthur, Switzerland, for his generous assistance in providing guidance, information and illustrations for this paper.

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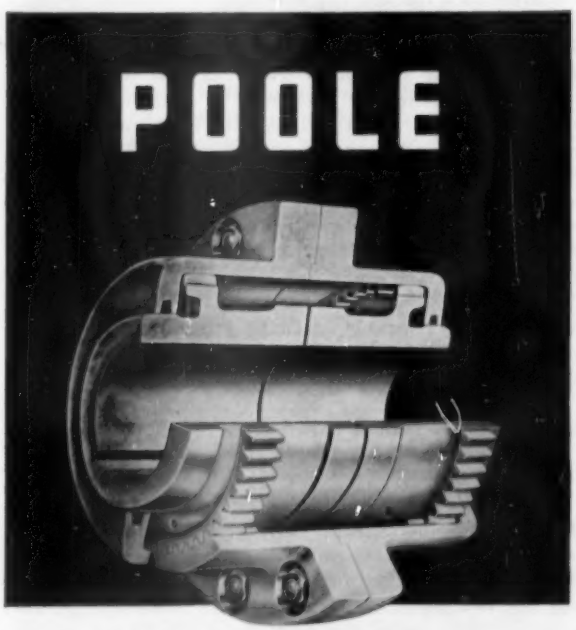
*Editor's Note:*

The above paper, reprinted in its entirety here, was part of the American Power Conference program reported on p. 62 and hence does not appear in the general meeting report.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# Highlights of American Power Conference—I*

Continuing its role as a leading forum for the power industry, the American Power Conference in its seventeenth annual meeting held at the Sherman Hotel in Chicago on March 30, 31–April 1, achieved new heights in the quality of its programming and quantity of its attendance. Presented at the conference were topics ranging in technical interest from solar energy through network analyzers to water treatment and having social and economic considerations as varied as the potential supply of engineers for the utility industry and the ramifications of multi-purpose projects using water for irrigation, navigation and power. Nor were conventional steam plants and the growing area of atomic power negelected by this outstanding meeting sponsored by the Illinois Institute of Technology with the cooperation of leading engineering societies and a large number of universities. R. A. Budenholzer and E. R. Whitehead of Illinois Institute of Technology acted respectively as director and secretary of the conference, ably assisted by a well chosen industry committee under the chairmanship of D. A. Sullivan of the Commonwealth Edison Company of Chicago.

"Where We Stand Today in the Utility Industry" was the subject of the opening address by **John W. Evers,** president of the Commonwealth Edison Company. Pointing to the evolutionary nature of engineering developments since the inception of the central station, Mr. Evers stated that the new horizons in atomic power demand the same brand of vision and courage shown by industry pioneers more than fifty years ago when the steam turbine was first being adopted. He added that there is reasonable certainty that nuclear power will some day compete economically with conventional plants, perhaps before 1965.

### *ASME Luncheon*

At a luncheon sponsored by the ASME, **Harold Quinton,** president of Southern California Edison Company, emphasized that the electric utility industry is essentially an engineering business, with its engineers being responsible for enormous expenditures of money as well as a dependable supply of vital service. He pointed out that engineering accomplishments which are often highly publicized in other industries are considered routine in the utilities, which are in some respects remiss in not making more generally known these technical achievements. Mr. Quinton added that there is a unique feature of the utility industry which is not widely known but which should be of great interest and considerable attractiveness to young engineers. This is the complete freedom of exchange of ideas, experience, developments and progress which takes place between utility companies and their suppliers and through engineering societies and trade organizations. It is this free interchange and rapid communication that enables the utility industry to make rapid technical progress.

### *All Engineers Dinner*

Speaking at the All Engineers Dinner, **Alexander M. Beebee,** president of Rochester Gas & Electric Company, raised the question, "Are Public Power Programs in the Public Interest?" He concluded that the principles underlying public power programs have outlived their usefulness, no longer serve the public interest and therefore should be revised. If our country is to grow and prosper, there must be *equality of opportunity* and *equality of taxation*, without having certain groups or certain areas avoiding their fair share of the tax burden and either enticing or competing with industries from other areas.

To correct present inequalities, Mr. Beebee urged the following three steps:

1. The present policy of "preference" in the sale of power from public developments is discriminatory and should be eliminated.
2. When private enterprise fails to develop sound multi-purpose programs for the public good, we cannot criticize the government for doing so.
3. Although many public power programs have or are now considering financing their programs by tax-free bonds, the loss in taxes can be greater than the apparent reduction in interest charges, thereby benefiting a few at the expense of the many.

### *AIEE Luncheon*

**Clarence H. Linder,** vice president of General Electric Co., addressing a luncheon sponsored by the AIEE, predicted that the requirements for designing, building and maintaining the specialized machines that will go into automatic factories will increase the demand for technical manpower. He stated that the fundamental force acting to put a premium on technically trained manpower is the tremendous rate at which technology is growing, both in volume and complexity. But engineering training must not be too narrowly technical, for the young engineer, in addition to broad training in mathematics and the physical sciences, must have some education in the humanities, the social sciences and in the communication of ideas. Pointing out that a large number of intellectually qualified people fail to emerge as college graduates, Mr. Linder suggested that industry apply familiar techniques of motivating people in encouraging secondary schools to interest pupils in going on to college.

### *Utilization of Solar Energy*

At the concluding luncheon sponsored by the Western Society of Engineers, **Prof. Farrington Daniels,** chairman of the department of chemistry at the University of Wisconsin, stressed some of the impelling reasons for the parallel development of atomic and solar energy resources. With the world united physically by instantaneous communication and rapid transportation, complacent isolation has disappeared, and in its place has come intense competition for the good will of all nations. In addition to humanitarian desires, there is an understandable selfish motive to help the non-industrialized nations attain a higher standard of living. Prof. Daniels suggested that we must begin to think of atomic and solar energy competing with manpower in Asia and Africa.

* A continuation of this report will appear in the May issue.

*Water Treatment*

There were four separately scheduled sessions on Water Technology. The opening one was confined to demineralization in its various aspects while the others treated various individual subjects. The lead paper "Demineralization of Makeup for Public Utility Plants" by **J. A. Wallace,** and **L. W. White,** Iowa Electric Light and Power Company dealt largely with the Prairie Creek Power Station demineralizer, a 40 gpm, two-stage unit owned by the Central Iowa Power Cooperative and operated by the authors' company. Earlier experience had dictated demineralization or evaporated makeup rather than zeolite softening due to previous excessive silica deposits in turbo-units in addition to loss in capacity and efficiency. There was also much concern over the excessive thrust on the thrust bearings.

Based on a cost of $3.70 per hundredweight for sulfuric acid and $5.45 per hundredweight for caustic soda, the cost of demineralized water at Prairie Creek is 42 cents per thousand gallon for regenerating chemicals only. This is considerably higher than the theoretical value, but it was held to be expected since the full 28,000 gal. capacity per regeneration of the cation unit is regenerated at 20,000 gallons. In addition, the capacity of the anion unit is 128,000 gallons and it is regenerated at 90,000 to 100,000 gallons. Since the cost per kw is affected only slightly, the unit is operated on a gallonage basis rather than by tests. Approximately every six months these units are run to capacity to find out whether or not either or both units are losing capacity. To date both the cation and anion units are well above the predicted capacity and there has been very little, if any, attrition or backwash loss of resin.

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**T. J. Judge** and **C. L. Davis,** International Paper Co., keyed their remarks to the subject, "Demineralization of Boiler Feed Makeup for Paper Mills." In their opinion demineralization of water, by virtue of its excellent effluent, is fast becoming the most preferred method of treatment for boiler feedwater makeup. It is particularly true in the power plants of the pulp and paper industry, where the amount of boiler water makeup approaches or exceeds 40 per cent of the total steam flow. Operating information on five such plants, treating approximately nine million gallons per day, provides the material for this paper.

Good treatment of boiler water makeup is reflected in the power plant's performance. The use of demineralized water has contributed materially toward reducing maintenance, improving efficiency, and increasing availability of equipment. The most outstanding improvements are the reduction of boiler scale, the elimination of harmful carryover in the steam, and the reduction in boiler blowdown.

The life expectancy of the anion resin is the greatest item of concern about operating the demineralizing plants. A more stable resin, or an economical method of reconditioning it, would solve the biggest problem in the opinion of the authors.

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"Treatment of Makeup Water With a 4-Bed Demineralizing Plant" by **W. M. Mayer,** Central Power & Light Co., describes the installation the author's company made for Unit No. 1 of Lon C. Hill Station, a 630,000 lb per hr steam generator operating at 850 psig and 900 F at the superheater outlet. The demineralizer for treating feedwater makeup was sized to provide 1.5 per cent makeup at 100 per cent load factor continuously if required, although the average requirement was expected to be less than 1 per cent makeup with a load factor of 60 per cent. Provisions were made to double the capacity of the demineralizer by simply adding resin to the exchangers, so that it would satisfactorily handle Unit No. 2. In view of the trend toward higher pressures and temperatures it was deemed advisable to obtain equipment which would provide the highest possible water.

The equipment finally selected was an Infilco single-line four-bed plant with degasifier. Both cation exchangers use high capacity styrene resin, the primary anion exchanger uses a weak base resin and the secondary anion exchanger a Type 1 strong base resin. Regeneration is, in effect, counter-current. All the acid required for regeneration of the primary cation unit is first put through the secondary cation exchanger and all the caustic required for the primary (weak base) anion unit is first put through the secondary (strong base) anion exchanger.

A table furnished with the paper gives typical operating results on the unit. The capacity of the primary cation unit is better than design; however, this can be at least partly attributed to the increased regenerant level currently being used. The total acid has been increased to 233 lb which is equivalent to 7.5 lb per cu ft of resin for No. 1 cation and 14.5 lb per cu ft for No. 2 cation. This increase in acid was dictated by the variable water supply. A slight increase in acid consumption also resulted.

A loss in capacity on No. 1 anion exchanger has occurred. Long, fast rinses are also being required. An investigation on this is currently being conducted.

A high quality of water in sufficient quantities has been produced at all times. The plant is put on line when the conductivity of the final effluent drops below 7 micromhos. At the end of a run the conductivity of the effluent rarely gets as high as 5 micromhos. During most of the run the conductivity is about 1.5 micromhos. Silica checks have shown readings of less than 0.01 ppm for the greater part of a run with a slight increase at both ends of a run. The secondary units, aside from their ascribed functions, serve as good assurance that a high quality effluent is obtained. Even with sulfation of No. 1 cation, which has occurred, no discernible change in water quality was noted. The excess capacity of the two secondary units makes the single-line four-bed plant a consistent producer of high quality water.

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**Russell C. Alexander,** and **Jack Korenthal,** Department of Water and Power, Los Angeles, Calif., presented as their paper "Centralized Control of Boilers and Feedwater Chemical Treatment at the Valley Steam Plant." The authors traced the evolutionary progress of water treatment systems in the plants under their organization's control up to the Valley Steam Plant which they feel has arranged its water treatment equipment in a manner compatible with the modern trend for more effective use of manpower and protection of water cycle equipment.

Of outstanding interest at Valley Steam Plant is the central sampling, testing, control, recording and chemical

feeding stations. One such unit is installed for each pair of generating units. These stations provide for testing, chemical treatment and quality control of feedwater and boiler water and testing of steam and condensate from various parts of the water-cycle. Included in each of these stations are quantities of dry chemicals, weighing and dissolving equipment, solution storage tanks and various unit chemical metering pumps with their associated controls. Complete facilities for the various analyses that are carried out is provided at each station, thus eliminating the transporting of samples.

The centralization of all functions of sampling, testing, chemical feeding and blowing down provides not only the means of, but also the incentive for, adherence to more narrow limits of concentration for the entire cycle.

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The paper, "Filming Amines—Use and Misuse in Power Plant Water, Steam Cycles," was jointly authored by **J. F. Wilkes** and **Dr. W. L. Denman** of Dearborn Chemical Co. and **Dr. M. F. Obrecht,** Michigan State College.

The protection of power plant water-steam systems against corrosion is a never-ending battle, in the opinion of these authors, and it begins with design of steam generating-distribution facilities, and associated feedwater conditioning equipment. Properly designed and operated external treatment processes and steam generator auxiliaries will reduce oxygen and carbon dioxide in steam to a minimum, which are identified as increasing the rate of corrosion attack. However, oxygen may enter condensate systems thru leakage; also, traces of carbon dioxide may concentrate at various points in the system and will cause accelerated corrosion.

Nitrogen-containing compounds of which amines are typical, currently provide the most effective chemical control of corrosion in steam-condensate systems. Both ammonia, and amines such as morpholine, cyclohexylamine and benzylamine have been used in power plants for control of corrosion, reduction in iron pickup, and protection of wet steam areas in turbines. These agents function by neutralization of carbon dioxide, and by adjusting pH of steam condensate.

Another group of amines which protect condensate systems by formation of protective films offers definite economic advantages, since they are required only in low dosages and do not function by neutralization. Filming amines protect against both dissolved oxygen and carbon dioxide attack, this protection being substantially independent of concentration of either of these dissolved gases.

Inhibitor dosages are independent of dissolved gas concentrations, since filming amines do not function by neutralization. Filming amine inhibitors increase heat transfer efficiency by removal of corrosion deposits, and promotion of dropwise condensation.

Pitfalls to be avoided in filming amine application have been presented. Even though general rules for successful application are established, each plant must be studied individually to insure most economical and efficient use of these film-forming inhibitors.

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**C. L. Mead,** General Electric Co., supplied a paper on the highly interesting subject of "Conditions Where Sticking of High Pressure Steam Valves May Occur." This sticking of high-pressure steam valves has caused increased maintenance, particularly on steam turbine-generator sets in power plants built in recent years operating at higher temperatures. The advent of reheat turbines has made the situation more troublesome since many more high temperature valves are employed in the control of steam to the turbine.

The amount of valve steam sticking that occurred prior to about 1941 was of little consequence. The maximum operating temperatures then were around 950 F. At this temperature, however, there was evidence that oxides were building up on the valve stems and causing sticking on a limited number of turbines. After cleaning them once, rarely was there any more sticking reported on those valves.

The stem-sealed stop valve was developed which shut off the steam leakage entirely when the valve was in the open position. This enabled the use of larger clearances on the order of 10 to 12 mils on the diameter since leakage occurred only while the valve was being opened or closed. The stem-seal was designed with a conical surface to prevent the valve stem from vibrating. The first such valve was put in service in 1942, and, since that time there have been no reports received of these valves sticking due to oxide build up. The control valves, having the smaller clearances (6 to 8 mils) determine when the stems and bushings should be cleaned by showing signs of sticking. The stop valve stems and bushings have approximately the same amount of build up but maintain adequate clearance for freedom of motion since their initial clearance is larger. The stem-seal feature also prevents build up of steam carryover deposits on the stem such as silica. Since there is no steam leakage past the stem, no boiler compounds can be carried to and deposited in this clearance area.

The increase in operating temperatures to 1000 F and higher has brought an increase in the amount of build up on the stems and bushings and an increase in the rate of build up. This has resulted in more sticking of the control valve stems, necessitating more frequent cleaning. About 1952, the stem and bushing clearances of all General Electric turbines were increased an additional two mils on the control valves (total now 8 to 10 mils) to enable the turbine to run longer before removal of the build up was necessary. The increased clearance introduces more steam leakage for a short time until the build-up brings the clearance down to the former dimensions. It appears that this change has resulted in a marked reduction in complaints.

Surface hardened nitralloy has become the standard material for valve stems and bushings in the main and reheat steam lines for all turbines operating at temperatures of 1000 F or less. For operating temperatures of 1050 F or higher, a stronger material with expected better corrosion resistance is used. Some form of 18-8 chrome-nickel steel with hardened surface has been used for this application. The same initial clearances are maintained regardless of the temperature or the material used.

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"Blue Blush Characteristics," a paper by **Frederick G. Straub,** University of Illinois, followed and it reported the results of an investigation of the so-called "blue blush" growth which forms on the valve stems and bushings when high steam temperatures are involved. The results indicate that the growth is the result of an oxida-

tion of the iron in the metal by the superheated steam. The action of the steam on various alloys and surface coated metals is reported.

The conclusions which appear evident from the results of these tests and the steam plant operating results are as follows:

1. The hard adherent iron oxide film forming on valve stems and bushings is magnetic oxide or iron resulting from a reaction of the iron in the base metal with the superheated steam.
2. All nitrided metals which have been reported used in valve assemblies and which have been tested show an appreciable steam oxidation rate at the temperatures of the tests.
3. The 440-A Chrome Steel was found to be very resistant to the steam attack.
4. Several stainless steels are resistant to this action of the steam.
5. Chromium and Lustralloy plating appear to show resistance to attack when plated on corrosion resistant base materials.

### *Cooling Towers*

A two paper session on the rôle of cooling towers was presented. One of these was the paper "Cooling Towers for the Power Industry" by **F. J. Lockhart, J. M. Whitesell,** and **A. C. Catland,** The Fluor Corp.

Steam power plants must have ample, dependable, and economical cold water. At one time enough cold water was supplied by nature in rivers, lakes, and other sources to be used on a once-through basis. However, water conservation regulations and anti-pollution legislation increase each year; water is less available, or more expensive, or at higher temperature. All industries using cooling water find greater economic attraction toward reusing cooling water over and over again. There is a definite increasing trend towards the use of cooling towers in steam power plants.

The basic desire is to locate a steam power plant so that electrical power can be delivered to load centers or existing transmission facilities at the lowest possible cost. In the past, plant sites were selected with respect to three main factors: (1) supply and cost of fuel, (2) available water for cooling, and (3) distribution costs. The use of a cooling tower eliminates the need for location by rivers, lakes, or oceans, and permits a more optimum location with respect to fuel and distribution costs.

Generally speaking, the once-through use of water from rivers, lakes, and oceans under average conditions requires lower capital expenditures and lower operating costs than the use of recirculating water from a cooling tower. Although true, this statement is subject to so many qualifications that considerations of specific conditions must be given to each individual plant. Excellent discussions of such economic comparisons, including the turbine, condenser, and cooling tower combination, have been given by Le Bailly and Elliott.

The selection of the cooling water system must include considerations over the anticipated life of the plant, and not just the past and present water availability and temperature. River and ocean waters are subject to problems of level variations, channel or shoreline variations, and possibly higher temperatures and decreased supply if other industries locate upstream. A cooling tower offers a more dependable supply and temperature of water.

Approximate costs of cooling towers for estimating purposes have been published in the past, but these were based primarily on towers where energy was not an important factor in evaluation. A recent survey article by Knowlton has given sizes, costs, and horsepower requirements for 52 cooling towers in steam power plants. These reported data were presented with illustrations accompanying the paper to give approximate costs.

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The second paper, "Cooling Towers—Their Influence Upon Prospective Plant Sites" by **R. W. Gausmann,** Indianapolis Power & Light Co., started out by recognizing that cooling towers are playing an increasingly important part in the selection of steam power plant sites. As an example, in Ohio, there is a mouth of mine power plant of over 200 mw size depending entirely upon cooling towers for condensing water even though the Ohio River is only 25 miles distant. No longer is it necessary to scour the countryside looking for sizable rivers when planning for a capacity addition.

Drawing upon the experience of the Indianapolis Power & Light Company in selecting locations for new capacity additions, this paper discussed (1) annual costs of cooling towers as compared with other variables normally affecting the selection of a plant site; (2) means other than cooling towers for supplementing river flow including deep wells, spray ponds and evaporative surface cooling; (3) open vs. closed cooling tower systems; (4) optimum spacing of plants upon a river.

The trend toward ever-larger "super" plants continues today where large blocks of energy are required. The plants building along the Ohio River to supply the tremendous demands of the Atomic Energy Commission program afford an excellent example of the modern "super" power plant. Nuclear power plants, when developed, are expected to be even larger and will still further tax our efforts toward finding adequate water.

In contrast, many systems are finding that low cost power may also be produced today by installing new capacity near load centers even though circulating water resources are limited at such sites. Developments favoring additions to plant capacity in such locations are: (1) right-of-way for transmission lines into urban areas is difficult to obtain; (2) modern units need less condensing water than older less efficient units. Present preferred standard reheat units operating at 1450 psi and 1000 F require only 60 per cent of the condensing water per kw output required by the 400 psi 700 F units of 25 years ago, and they require only 80 per cent of condensing water required by 850 psi 900 F units. Supercritical pressure, double reheat units now under development will use even less water. (3) The general trend toward 3600 rpm for single shaft units reduces the savings to be gained by high vacuum. Due to the higher leaving losses of these high speed machines, less effective use can be made of cold condensing water. (4) Experience has amply demonstrated that large plants can place dependence upon modern type cooling towers as their sole source of condensing water.

### *Industrial Power*

There were several sessions variously labeled Industrial Steam and Power, Industrial Steam Generators, Industrial Applications that were devoted to the indus-

trial field in one way or another. The paper "Fast Starting of 150,000 Lb per Hr Industrial Boilers" by **C. E. Morrow** and **R. F. Born,** Western Electric Co., Inc., covered an investigation to develop fast starting procedures for three pulverized coal fired boilers of this capacity in the Hawthorne Works Power Plant of the Western Electric Company. These boilers have generally been started according to standard boiler manufacturer's recommendations, the rate of temperature rise as measured by the saturation steam temperature not exceeding 100 F per hour. For these units, this represents an interval of about $4^1/_2$ hours, and considerable attendance is necessary when following a starting procedure of such duration. An outage of process equipment for that period is costly when an emergency condition arises requiring that an idle boiler be placed in service. On this basis it was considered most desirable to reduce the manufacturer's recommended starting interval by whatever amount that could be determined through a series of starting tests and a study of their results. Mr. Jefferson Faulkner reported results of accelerated starting procedures in 1952 on boilers of higher pressure design and capacities of well over one million lb per hr. This paper greatly stimulated interest in fast starting at Western, and this investigation was begun the following year.

A system of firing was developed so that large amounts of fuel input could be made, but temperature of the gas is reduced before reaching the high temperature superheater. This was accomplished by opening the upper burner air registers and firing only the lower two burners. If the wind box pressure is held sufficiently high, the unit can be fired at approximately 25 per cent of maximum rating with gas temperatures of less than 1100 F at the screen. Using this procedure, it was possible to place boilers on the line after 60 minutes of firing if the units had been off the line as long as 50 hours. Where outages were extended to permit cooling to room temperature, the starting interval was 90 minutes.

It was found that some distortion occurred in all of the runs, but in no case was the total difference in evaluation between ends of lower sidewall headers more than $^1/_4$ in., and averaged about $^1/_8$ in. In all runs circulation began slowly and the temperature difference between headers and water contained therein never affected operation.

Temperature differentials within the steam drum varied from the center to either end with the ends running as much as 50 F lower during steady operation. However, at points around the circumference at a cross-section the temperature differentials were never more than 20 F. The maximum difference between the end and center was 105 F. Because no distortion of the drum structure occurred, no overstress resulted. These observations were applicable to all runs.

After a few runs on this method, it was thought that a permanent thermocouple arrangement to measure the gas temperature entering the screen might serve as a control when fast starting procedures became a routine operation. A study of test data indicated that if the gas temperature entering the screen did not exceed 1100 F, neither the high temperature nor low temperature sections became over-heated when the superheater drain was partially opened. After a series of successful runs were made when operators proceeded from a standard instruction, it was decided to install a retractible thermocouple gas probe and indicating device.

"The Problems of Combustion Control" by **Paul Thanos,** Inland Steel Co., discussed the experiences of his concern with a power expansion program recently completed at their Indiana Harbor Works which included the installation of a new 200,000 lb per hr boiler. The combustion control for this boiler had several variables to contend with that are not ordinarily found in central stations or other types of industrial plants.

To begin with, the power generating system at the Indiana Harbor Works is isolated from any other. The electrical energy demands may fluctuate as much as 20 per cent of the total capacity and the instantaneous peaks even surpass the capacity. These conditions must be met in order to attain maximum use of production facilities and maintain flexibility of customer service.

Furthermore, by-product fuels must be utilized to a maximum in satisfying these conditions so as to keep our "out of pocket" fuel costs to a minimum. Among these by-product fuels are blast furnace gas and coke oven gas which have a heat value of about 95 Btu per cu ft and 540 Btu per cu ft, respectively.

Their No. 3 A.C. Station (the location of the new boiler) has a capacity of 30,000 kw and will use either blast furnace gas, coke oven gas, or oil, either singly or in any combination depending on the availability of the by-product fuels. Natural gas, when available, is also introduced into the blast furnace gas main to enrich the gas.

The main source of fuel here is blast furnace gas which is produced as a by-product from two blast furnaces. Due to only two-furnace operation the pressure and volume of gas varies considerably particularly when one furnace is on cast. A set minimum pressure must be maintained on the blast furnace gas main at all times and is controlled by the amount of gas being used for steam generation. During a cast period, the flow of gas to the boilers must be reduced immediately to maintain this minimum pressure. When the flow of blast furnace gas is reduced, auxiliary fuels must be burned to replace the loss of blast furnace gas. Besides the fluctuations in gas pressure many problems result from the dirt contained in the blast furnace gas. Past experience has shown the difficulty of maintaining operation of flow control valves in a blast furnace gas line.

The supply of coke oven gas is limited and allotted in definite quantities that may be reduced or cut off entirely on a moment's notice. An adequate source of fuel oil is always available and this fuel is depended on to compensate for any loss of blast furnace gas. Since blast furnace gas and coke oven gas are by-product fuels, every effort is made to use these fuels to the limit of their availability.

An additional variable is added in the load fluctuations at No. 3 A.C. Station which will vary from 10,000 lb of steam per hr in a few second, to over 100,000 lb of steam per hr in a few seconds, although the latter does not occur as frequently.

The automatic controls for this new boiler therefore have to recognize all these variables so as to fully utilize by-product fuels, as available, and do so with maximum possible efficiency. Furthermore, with the four older boilers being manually controlled this task becomes even more significant. These controls are rather fully described and consist of a combustion system that will maintain steam pressure by burning blast furnace gas

with the correct fuel-air ratio so long as blast furnace gas is available, but will substitute fuel oil for blast furnace gas whenever there is a deficiency in blast furnace gas. The use of coke oven gas will not upset the fuel-air ratio in the furnace, nor will it preclude operation of the boiler on automatic control provided the total coke oven gas flow is less than the total fuel requirements.

A limit switch is operated by the oil flow regulator setter to signal the operator that there was a deficiency of blast furnace gas so that he might set up his oil burning equipment. Once he has oil to the burners he sets the minimum oil flow that gives him satisfactory burner operation, and control is completely automatic again.

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"Air Preheater for Small Power Plants" by **W. E. Hammond** and **C. L. Brown,** Air Preheater Corp. opened with the statement that improvement in operating efficiency is the "rainbow" all operators and designers must perpetually follow.

The boiler industry has attacked the first cost problem by introducing the standardized boiler. Similarly, the authors' company is now marketing a small standard air heater with similar advantages. The rotary regenerative air preheater extensively used in the large installations has now been designed for use with small industrial boilers from 25,000 lb per hr to 150,000 lb per hr.

While it is customary to evaluate the advantages of heat recovery equipment by comparing fuel savings to capital charges, it should be noted that this approach does not include maintenance. The use of preheated air plays a significant part in the burning of lower grade fuels containing sulfur and other objectionable material. The combustion process is accelerated so that less $SO_3$ is formed in the flue gas. The presence of $SO_3$ in the flue gas leads to severe corrosion and plugging problems so that every effort must be made to keep it to a minimum. Raising the air temperature from 375 to 550 F results in a marked improvement in operation and less $SO_3$ is present.

The use of high temperature air reduces the incidence of unburned carbon leaving the furnace and entering the heat recovery equipment. The presence of this carbon seriously aggravates the corrosion and plugging problem since it contains a high concentration of sulfuric acid which makes it very sticky and provides a binder for dust buildup.

In regard to the weight and volume of the regenerative type of heat exchanger, it is significantly smaller and lighter than other types. This results from the fundamental nature of the heat transfer involved, which is pure counterflow, and due to the fact that more compact heating surface can be used. Comparison of preheater volumes indicates that for the same recovery the volume of the tubular heater will be six to ten times that for the regenerative heater, depending on tube size and spacing.

Another factor to be considered in the selection of air preheaters is that of metal temperature. Conventionally, metal temperature is accepted as being the average of the air and gas temperatures so that, at the cold end of the heat exchanger, the coldest metal will be the average of the entering air temperature and the exit gas temperature. In the regenerative heater, tests and experience have demonstrated that the actual metal temperature is 20 to 30 degrees above this average.

*Water Resources*

**R. J. Pafford, Jr.,** Corps of Engineers, in his paper "Use of Water for Irrigation Navigation and Power" pointed out that this nation has entered upon an era which is making new and tremendously heavy demands upon our basic natural resource of water. The economic strength of America, both from the standpoint of domestic progress and national security, is inextricably related to adequate water supply.

Today, water is no longer merely a regional problem in certain areas such as the semi-arid west. It has become a national problem of steadily increasing gravity. Demands have increased at such an accelerated rate year by year, that now there is no part of the country free from the necessity of giving serious thought and effort to the inter-related problems of river regulation and water supply.

Water may be considered a renewable resource in that it passes again and again through nature's hydraulic cycle. Therefore, the conservation of water is not so much a problem of saving a decreasing supply for some future need, but the control and use of water to the optimum advantage of all. Its energy must be harnessed, its destructiveness tamed and its irregularities modified. It must be more equitably distributed and made more dependable in supply.

Mr. Pafford suggests the following course of action:

(1) Comprehensive river basin programs, with careful integration of individual projects and developments into an overall basin system, to obtain optimum use of the water resources available.

(2) Multiple-purpose water development projects for joint service to several water uses, to minimize costs for each water use.

The author then went on to describe what he termed an outstanding example of comprehensive, multiple-purpose water use development for these and other purposes, namely the Missouri River Basin, where major units now coming into operation are reported as already beginning to demonstrate their actual capabilities.

*Stacks and Chimneys*

**C. G. Merriman** and **M. S. Ozker,** The Detroit Edison Co., delivered a highly valuable paper entitled "Dynamic Behavior of Power Plant Stacks Under Wind Loading." The authors pointed up the reason for today's increasing attention to stack loading by stating that the prime purpose of power plant stacks today is radically different from that of thirty-five years ago. Then, their function was to create natural draft sufficient to burn the fuel. With the advent of mechanical draft, an absolute necessity with large steam generators, the function of stacks as a means for creating draft diminished. Modern stacks are for the sole purpose of effecting the dispersion of the products of combustion; this function they must perform in an effective manner to prevent excessive pollution at ground level. The particular matter, such as fly ash, can be collected by efficient dust-arresting equipment. Large amounts of flue gas, however, must be discharged into the atmosphere. As the result, tall power plant stacks are necessary. These high stacks give rise to problems in structural stability and dynamic response to wind excitation is of particular concern.

Most of the difficulties and damage that have been

experienced with stacks have occurred during construction before the lining has been installed. Unlined steel stacks are subject to ovalling and cantilever oscillations. Ovalling of the barrel disappears when the steel shells are masonry-lined or structural spiders are added. Where cantilever oscillations have occurred, or where instability has been experienced during construction, different methods of correction have been employed. Batteries of stacks arranged in a row, as is common in power plants, have been structurally interconnected in pairs or continuously near their tops by struts or trusses. Struts normal to the line of stacks have been joined from their upper works to adjacent structures. In one instance, friction dampers have been incorporated in these struts to dissipate the energy imparted by the wind and thus minimize the excitation. Another method utilizing hydraulic dashpots has been devised, and was described in this paper.

The authors gave rather detailed experiences in stack behavior problems and described the experimental data needed for solution of the particular problem as well as the means of obtaining this data.

### *Central Station Steam Generators*

The first one of a two-paper session on Central Station steam generators—"The Monotube or Once-Through Boiler for Conventional or Supercritical Pressures" by **A. T. Hunter,** Combustion Engineering is reproduced in full on p. 57. The second paper on this session, "The Operation of Large Central Station Steam Generators" by **Gerald V. Williamson** and **John K. Bryan,** Union Electric Company of Missouri, presented in a capsule form the accumulated experience of the authors.

In the past five years, approximately 125 supersize high-pressure boilers, each capable of producing a million lb of steam per hr or more, have been placed in operation or now are under construction for public utility service in this country. Among the first of the supersize boilers, and perhaps the first for midwestern coals, were two ordered for Venice Plant of the authors' company in 1947. Such boilers, then, are in about their tenth year. All are of interest, many of them with unusual design features and operating characteristics. The success of these boilers is of prime importance to the industry, and their main features warrant understanding.

First and foremost of these features is the matter of size. Ever increasing size of units, is perhaps, the one factor most responsible for the new low cost of central station generation, and the industry must ever take the boldest possible steps in matching load growth to bigger and bigger units. Boiler sizes in the authors' company have more than doubled in the past quarter century. Industry-wide, single boilers are now being erected that will burn 5 million dollars worth of fuel a year; and boilers are on order where the annual fuel bill can exceed 7 million dollars. With respect to physical dimensions, a modern central station boiler may be 150 feet high and have a furnace cross-section area 25 feet by 50 feet, or larger. Further, the very largest boilers, corresponding to 300,000 kw turbine-generator size, are designed with twin furnaces. Largest units have two million lb per hr rating. In the past two decades boilers grew two to four times as fast as turbines, and now the two are locked in step with the modern single-boiler single-turbine.

The modern boiler's size is such that it must be remotely controlled; the large quantities of fuel, air and steam and the complexity of its operation dictate that much of its control must be automatic; the single-boiler single-turbine arrangement dictates that all operations for the entire boiler-turbine-generator-auxiliaries unit be coordinated by control from one central location. Central control is now almost universal for large-sizes.

The overall result of centralized control can be regarded as highly satisfactory, both to operators and station performance. There appears to be virtually no question among plant operators or designers as to the feasibility, safety, and economic advantages of centralized control. No longer is communication from turbine hall, to boiler house, to switchboard the complex problem it once was. All three are within talking-thinking distance of each other.

Higher initial steam conditions and the use of reheat have been very largely responsible for the steady improvement in central station efficiency during the past several decades. It has been the lot of the boiler to produce its energy output under these more demanding conditions, and this it has accomplished successfully. However, the efficiency of the boiler itself has not, indeed could not, improve in the same sensational manner as the efficiency of the plant as a whole: there were boilers in operation twenty years ago that regularly transferred to water and steam 90 per cent of the energy in the fuel burned. The best modern boiler the authors know operates at 92 per cent.

A problem plaguing operators recently concerns the first few weeks of operation, for during this period a large number of high-pressure turbines have been damaged by metallic particles carried into the machine with the steam. Presumably the "shot-blast" particles are picked up in the superheaters and reheaters of the boilers and in the piping connecting them to the turbine so these steps have been taken: (1) Piping and tubing is thoroughly cleaned at the fabricator's shop. (2) During shipment and storage, and then during erection, care is taken to keep foreign material out and to prevent corrosion. (3) Steam lines are blown out prior to admitting steam to the turbine. (4) Despite these precautions, it is now common practice to protect the turbine during initial operation by use of fine mesh strainers at the turbine end of the main steam and reheat lines. These strainers generally have $^1/_{32}$-in. openings, are removed after no more than a couple of weeks operation.

Proper chemical control of boiler water is at the very heart of the successful operation of large central station boilers. On the other side of the boiler tubes, the fireside, as well as the air preheater itself, the problem is one of keeping the surfaces clean and the heat absorption rates high. Involved are the equipment design, its operation and its fuel.

For large coal fired boilers, the use of water-cooled surface in the furnace is now known to be the important design factor affecting slagging conditions in the convection passes. A crucial function of the furnace has become that of cooling the products of combustion before they strike the hot and closely spaced superheater tubes, where troublesome slagging can occur.

The mechanical cleaning equipment, still called soot-blowers though soot is the least likely thing they'll encounter, has become an essential and integral design part.

# NEW CATALOGS AND BULLETINS

### Crown Couplings

Bulletin 2203, DeLaval Steam Turbine Co., is a 4-page release describing the manufacturer's line of crown couplings. An exploded view of the coupling and a table containing data for selecting the proper coupling for a given application are featured.

### Clean Water

A two-color, 34-page bulletin GEA-6096, designed to help civic leaders, municipal officials and sewage treatment experts dramatize the need for proper sewage treatment has been released by General Electric Co.

It contains facts on water pollution, a 4-step course of community action, examples of successful community campaigns and methods of obtaining public support for such programs.

### Recording Receiver

The recently released 12-page bulletin, Product Specification E 12-5, of the Bailey Meter Co., describes a receiver recorder for pneumatic and electric transmission systems. The device is explained in detail with illustrations, applications, operation, engineering and ordering specifications furnished.

### Piping Deposits

A new 4-page bulletin entitled "A Solution to the Problems of Deposits in Piping Systems" by Dowell, Inc. describes the advantages of the company's cleaning service and illustrates the three principal methods employed for this service. Schematic drawings picture the chemical, the pipeline pig and the jet mole method of applying the cleaning fluids.

### Relief Valves

A series of three 2-page bulletins, Nos. FR-1, FR-2 FR-3, from the A. W. Cash Valve Mfg. Corp., treat the company's new Type FR back pressure relief valves. This new patented series of valves, available in pipe sizes from $^1/_2$- to 2-in. in iron, bronze, stainless steel or monel bodies, is suitable for pressures up to 400 psi.

Bulletin FR-1 gives construction data on the new valve, how its "floating ring" works and some of its features. This ring is credited with being free to move laterally in any direction to find perfect alignment with the spherical seat disk. The combination of the spherical seat disk and floating ring eliminates, according to the manufacturer, any need for piston and cylinder.

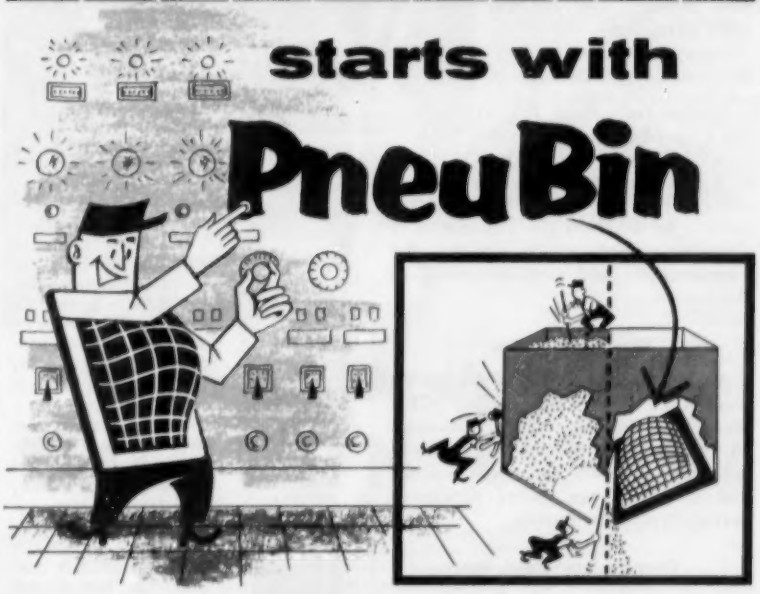
### Cork Applications

Industrial applications and specifications for material and composition cork are available in the new 4-page Bulletin S-55 obtainable from the Dodge Cork Co., Inc. The physical properties and uses of the various corks are given as well as the SAE-ASTM and government equivalent specifications for cork compositions.

### Badger Bulletin

A new 8-page, comprehensive bulletin has been made available by the Badger Mfg. Co. outlining its broad services in four fields, namely (1) design and construction of process plants and process units, (2) design and/or fabrication of special processing equipment, including a variety of trays and boiling caps, (3) corrugated type expansion joints, both


AUTOMATION starts with PneuBin



**Pulsating Panels assure constant material flow from bins and hoppers**

Automation is an empty word if your production is interrupted by material hang-up in bins and hoppers. That all-important initial step of material introduction must move smoothly, flawlessly or the whole concept of automation is destroyed. PneuBin will solve your flow stoppage problems and reduce your operating expense. The PneuBin unit consists of steel-backed, neoprene, pulsating panels mounted on the inside walls of your present bins, and air controls to regulate the panels' action. By the pneumatic inflation of the PneuBin panels, the bin contents are positively displaced to insure free flow. Automatic inflation and deflation continues in cycles at whatever frequency is set on adjustable control. PneuBin operates off the regular plant air supply.

PneuBin decreases plant operating costs by reducing maintenance and adding to the life of your bins; insures constant material flow; and greatly increases personnel efficiency through its quiet operation.

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direct flexing, self-equalizing and non-equalizing, (4) vapor compression stills for purifying water in production volumes.

### Gages

Publication 54-1060-210 of the Hays Corp. portrays in 4 pages a new design in draft gages, the manufacturer's Vertiscale Gages. The basic operating mechanism consists of a diaphragm, enclosed in a cast metal housing, whose force and movement are balanced against the force of calibrating springs. Linkage transfers the resultant force to a pointer to indicate the magnitude of the draft. Each unit is equipped with a 3-way atmospheric vent cock with a test fitting to provide easy connections to test gages. This same 3-way cock affords a ready, one-man check of the zero setting. The bulletin describes other advantages.

### pH Control

Process Data Sheet 700 (1) "L & N pH Control of Cooling Tower Water," issued by Leeds & Northrup Co., gives in 4 pages suggestions on measurement and control of the pH of cooling tower water. In addition the manufacturer describes equipment to perform the measurements and exercise control of the water.

### Clad Steel Plates

A special 6-page booklet of the Lukens Steel Co., "Price Comparison—Clad Steels vs. Solid High Alloys," discusses 16 standard alloy claddings on a variety of backing steels and shows how designer and fabricator can realize significant savings in equipment costs.

### Continuous Blowdown

A simplified chart to rapidly calculate the savings possible through heat recovery with automatic continuous blowdown is offered by Henszey Co. The chart is based on total dissolved solids in the boiler water and the permissible concentrations to determine total blowdown. Recommendations are given for the selection of blowdown equipment in accordance with normal conditions of boiler operation.

### Canned Pumps

A recently published 12-page paper detailing the design and development of centrifugal pumps that have no seals or stuffing boxes has been made available by the Chempump Corp. Included are detailed data and curves regarding temperature, pressure and the effects of the pump design on electric motor operation.

### Variable Speed Drive

The 4-page bulletin, K-100, of the Cleveland Worm and Gear Co., describes the patented design features of the Cleveland Speed Variator which is a mechanism based on the patents of Jean E. Kopp, Swiss engineer. The maker claims the drive is rugged, dependable, employing the rolling action of a series of balls to perform the mechanical transmission requirements.

### Battery Selection

A revised, 20-page, 8½ by 11-in. manual, Bulletin 210, dealing with batteries for standby power, emergency lighting and switchgear applications has been made available by the Electric Storage Battery Co. Selection techniques are emphasized as well as a discussion of battery maintenance procedures.

### Coal Valve

Stock Equipment Co.'s new coal valve makes up the subject matter of its recent 8-page Bulletin No. 97. This valve is said to operate quickly and reliably even after long periods of no operation because of its self-cleaning ladder racks and multiple faced pinions. The coal gate rides on large rollers fitted with ball bearings and adequate grease seals.

### Reboiling Deaerator

The 4-page bulletin, No. 3677, describes the Permutit Co.'s reboiling deaerator with direct contact internal vent condenser said to heat and deaerate water in three stages. The device is claimed to work over a wide range of flows from 1 to 100 per cent of rated capacity and effects a thorough removal of residual non-condensable gases and dissolved oxygen in the effluent to less than 0.005 ml/l.

### Magnetic Pulleys

The 8-page bulletin PY-260 featuring the Hercules permanent magnetic pulley of the Hamer Mfg. Co. carries diagrams, performance data, specifications and a guide for selecting the proper size. These pulleys automatically remove tramp iron from coal, ore and similar material.

### Multi-Stage Pumps

The Ingersoll-Rand Co. has recently made available a 12-page bulletin, Form 7096, describing their vertical multi-


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All sizes to fit your gages
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mid-year
CHANGE-OVER
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When you
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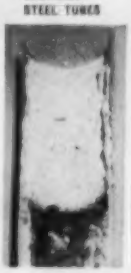
Re-tube Preheaters this summer

ORDINARY STEEL TUBES



BARROW'S VITRALLOY PREHEATER TUBES

When you re-tube preheaters this summer make your own convincing test of Barrow's VITRALLOY. Install a representative section of these clogging and corrosion free tubes . . . side-by-side with the ordinary steel tubes you usually use. Then compare operational performance . . . watch just a plain water wash down keep VITRALLOY free and clear . . . see how they outlast ordinary steel tubes (of same wall thickness and installed at same time). VITRALLOY Tubes (boro-silicate compound fused to base metal) resist corrosion . . . nip the vicious cycle of clogging and more corrosion before it starts. VITRALLOY also permits saving and re-use of more degrees of heat from flue-gas.

HOW TO MAKE YOUR VITRALLOY TEST

Get set by ordering your change-over tubes now . . . or if you prefer to first look at a "desk size" 6" length of VITRALLOY Preheater Tube, drop us a line. For each of your units, be sure and let us know the number, length and diameter of tubes . . . also sulphur percentage of your fuel.

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stage pumps. It includes sectional drawings, dimensions, installation views of the pumps in service. These units are designed for boiler feed, refinery, process and booster service for all pressures up to 1500 psi with capacities to 3500 gpm.

### Condensed Valve Catalog

A new simplified cross index in the Condensed Catalog 105 put out by Edward Valves, Inc., is said to permit easy reference to vital data on a wide range of available valve designs. Included are non-return, globe and angle stop valves, pressure seal design, angle uni-valves and small size globe valves designed for chain or extension operation in vertical lines.

### Thermocouple Air Converter

In a 2-page bulletin, A-714, the Swartwout Co. describes in detail their Type T3C thermocouple air converter which is said to enable users to retain their pneumatic recording and controlling panel components and yet employ the manufacturer's automatic system of all electronic process control.

### Gas Turbines

A revised 28-page bulletin, GEA-5516B, describes the General Electric Co. combustion gas turbines for power generation and mechanical drives. Gas turbine-steam turbine cycles, mechanical drive applications, design features, control and governing, generators, tables of characteristics, dimensions and weights are covered.

### Butterfly Valves

Builders-Providence, Inc. has included in its 4-page bulletin 650-L1, the advantages, sizes, pressures, velocities, operators and positioners on its newly expanded lines of tight-closing, rubber-seat butterfly valves. The bulletin shows general arrangement dimension prints of various size valves with manual, electric, hydraulic and pneumatic operators.

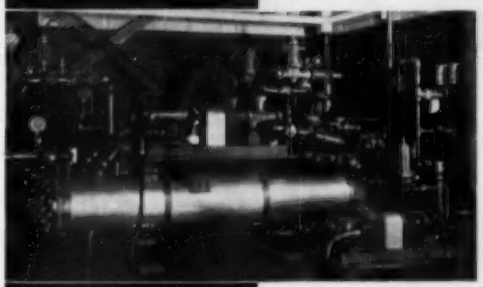
### All Molded Valves and Fittings

Circular 601, a 4-page release by the Lunkenheimer Co., describes the reportedly first all molded unplasticized polyvinyl chloride (PVC) valve and fittings recently added to the manufacturer's Luncor line. The material is said to be corrosion resistant, odorless, tasteless, nonporous and non-contaminating with a weight only one-sixth that of metal.

### Oil Blending

Diagrams and descriptions constitute the makeup of the 4-page Application


**ENCO**
**Fuel Oil Pumping and Heating Systems**



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**For heavy bunker oil or light furnace oil . . . 100 to 10,000 gallons per hour**

Enco systems employ one, two or more pumps and heaters, interconnected so that full capacity is possible with any combination of pumps and heaters. Flexibility of design permits the use of any combination of rotary pumps, with motor or turbine drive; or piston type steam pumps. Any part may be cut out of operation for inspection or cleaning, without shutting down, where two or more pumps and heaters are included in the unit system.

Heaters are insulated and jacketed with removable heads at both ends for cleaning without breaking any piping connections or removing any tube bundles.

Full automatic oil pressure and temperature control, with relief valves for each pump and heater. Permits delivery of oil with safety, and at proper temperature and pressure for efficient burning.

Each unit is built to order and delivered ready to place on foundation and for connection to the station piping.

Write for Bulletin OB-53 describing Enco Gas and Oil Burners; and Pumping and Heating Equipment.

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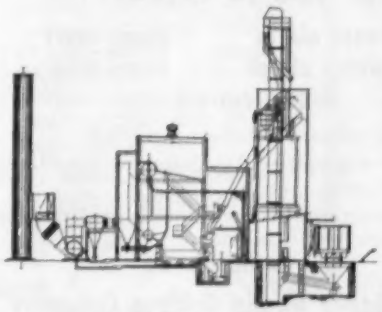
**MODERN COAL**

**The Fairmont Coal Bureau has made available to consulting engineers and equipment manufacturers a TYPICAL DESIGN for the small industrial steam plant. Prepared as a guide to good engineering it achieves maximum economy of investment and engineering costs, while featuring:**



- Fuel flexibility
- High efficiency
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**Fairmont Pittsburgh Seam Coal is the MODERN COAL. Enormous reserves and inherently favorable mining conditions guarantee ample supply and low production cost. Modern mining and preparation facilities assure uniform quality.**

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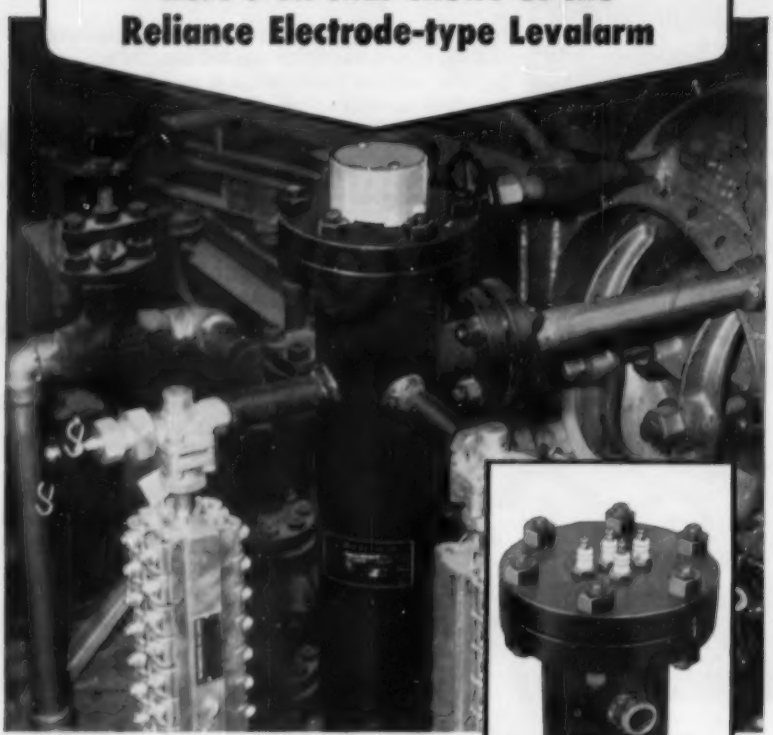
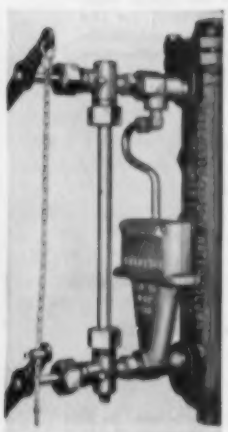
**Small Device Does Big Job!**

**Here's all that shows of the Reliance Electrode-type Levalarm**



*Cap removed showing electrode connection fittings*

**Boiler water connects own alarm system and fuel cut-out . . .**



**Isolated circuits make relays work for you to actuate...**

low water alarm — pump start
high water alarm — pump stop
fuel cut-out

*(or selection of these facilities)*

Upper photograph — Levalarm for pressures up to 1100 psi.

Lower photograph — Fuel cut-out Levalarm on low pressure water column.

**Write for Bulletin D2.**

**The Reliance Gauge Column Company**
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*The name that introduced safety water columns....in 1884*

**Reliance®**

**BOILER SAFETY DEVICES**


Memo L-25, released by Proportioneers, Inc., and entitled "The Continuous Blending and Proportioning of Fuel Oils." It illustrates the manner in which a two component blender automatically delivers a uniform blend of No. 5 fuel oil directly into tank trucks, tank cars, ships or storage.

### Worm Gears

Foote Bros. Gear and Machine Corp. have made available a 24-page catalog, "Engineering Manual SW No. 1," that lists the now available standard line of worm gear sets which can be purchased the first time as separate items from the reducer sets. The line covers the standard ratios from $4^1/_2$ to 71.

### Deaerator

Fred H. Schaub Engineering Co. has its 8-page bulletin No. 1300 devoted to its "03" deaerator. In the bulletin the design features of unrestricted venting, special vent condensing and a new heating method are described and discussed.

### Chlorine Gas Feeders

The 12-page paper "Principles of Chlorine Gas Feeders" by R. W. Pearce, Builders-Providence, Inc. as it appeared in Water and Sewage Works Magazine is available under the code number 840-L29. Photographs, diagrams, tables and flow sheets illustrate this material.

### Gas Analysis

A newly released 12-page booklet, No. 82, by the Burrell Corp. explains the Fracton, a new instrument for the analysis of light hydrocarbon gases. This method employs adsorption fractionation and line drawings are provided showing a detailed flow diagram as well as photographs of accessory equipment.

### Cooling Towers

The new J. F. Pritchard & Co. line of mechanical draft cooling towers, Lo-Line is featured in a 4-page bulletin 5.1.902 recently made available. This class cooling tower has a low overall height and attractive exterior to meet the trend toward suburban buildings.

### Ball Float Traps

Armstrong Machine Works released an 8-page bulletin, No. 289, for their line of ball float valves for draining water from gas, air or steam lines and for draining light liquids from gas under pressure. Physical data, an orifice capacity chart and installation diagrams are included.

### Refractory Arches

The Bigelow-Liptak Corp. has fea-

tured in its most recent catalog the company's unit suspended walls and arches for industrial furnaces.

### Water Conditioning

Supplementary treatments for boiler makeup water are discussed in the 4-page bulletin "No. 40 Series Supplementary Treatments" 28 X 8226. The bulletin points out that since no external treatment produces complete removal of objectionable material from makeup and contamination usually exists in condensate, further treatment is advisable and then proceeds to describe the company's series of supplementary treatments.

### Chlorine Feeders

Flow responsive or automatic proportional pacing of chlorine feeders is covered in the Sup. work Bulletin 840-K13 of the Builders-Providence, Inc. It describes several automatic pacing systems to solve a variety of chlorine feeding problems.

### Power Operators

Bulletin B-50-2, a 12-page booklet, describing the Conomoter, a pneumatic-positioning power operator for throttling control service has been made available by the Conoflow Corp.

### Dealkalizing Salt-Splitter

Publication No. 4567 lists the advantages and gives details of operation for the Cochrane Corp. dealkalizing salt-splitter. Included are descriptions of the chloride anion exchanger process the need for dealkalizing boiler feed and processing waters and points the way to achieve dealkalization.

### Cast Alloys

"Resistance of Cast Fe-Cr-Ni Alloys to Oxidizing and Reducing Flue-Gas Atmospheres" by J. H. Jackson, C. J. Slunder, O. E. Harder and J. T. Gow is a reprint from the *ASME Transactions* and is made available by the Alloy Castings Institute under the code number of GR-16.

### Scavenging Oxygen

The use of hydrazine in treating feedwater for high pressure boilers makes up the subject matter of the Milton Roy Co. Application Engineering Data Sheet, D-54-3. The advantages of the precise additions of this chemical are mentioned and a suggested application layout is furnished.

### Demineralizing Handbook

A comprehensive 40-page "Handbook on Demineralizing," Publication 5800-B, by Cochrane Corp. tells when to use 2-bed, 3-bed, 4-bed, mixed or mono-bed demineralizers. It also compares various methods of water treatment, as well as demineralizers and evaporators.

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W. A. TAYLOR & CO.
Tells how to use pH, chlorine, and phosphate control to reduce corrosion, scale, slime, sludge in heating and cooling systems.
100 pages of factual data on theory and application of pH, chlorine, phosphate, nitrate control and complete boiler water analysis. Useful every day. Clearly written, concise, easy-to-read. Data based on 25 years service to industry. Also illustrates and describes complete line of Taylor Comparators, tells how to use Taylor sets in your plant.
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### Boiler Feed Pumps

Roy E. Roth Co. has released a 12-page booklet, Bulletin No. 107, describing their new line of regenerative turbine pumps designed for boiler feed service up to 1000 hp and operating at pressures up to 300 psi. Ten models are available in the company's 2000 series and nine models in the 3000 series in standard fitted, bronze fitted, all iron, and all bronze.

### Filters

Filter Facts No. 1, a 12-page publication of the Engine Life Products Corp., details filtering equipment and their relation to lubrication systems, contaminants, filter materials, limitations of chemical filters, filter construction, the effect of detergent oils, size and installation types.

### Demineralizing

A new reprint T-127, "The Status of Demineralizing in Today's Plants," available from Graver Water Conditioning Co., presents a discussion on the subject of demineralization for boiler feedwater, gives curves for estimating costs and performance and furnishes flow diagrams on the basic types of units.

### Stock Gears

Features of the large 200-page Universal Gear Works, Inc. catalog are specifications and prices for 8000 stock items including gears, sprockets, chains and splines. Gears and sprockets from $^1/_8$ in. are produced.

### Torque Converters

An 8-page catalog released by the Clark Equipment Co. devotes itself to the company's line of Torcon Torque converters. Models are shown as well as attachments for specific adaptations.

### Turbine Generators

General Electric Co. in a new 52-page booklet, GEA-3277C, describes condensing and non-condensing turbine generators and their applications to electric utilities and industrial plants. Cross-sections, schematic drawings, close-ups and installation photographs are employed to picture the equipment features.

### Super Refractories

A 24-page booket, "Properties of Super Refractories" released by the Carborundum Co., gives the latest physi-

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*specifies*

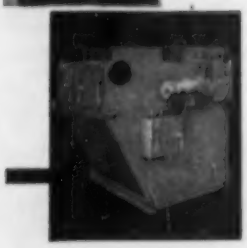
**Richardson**

**Like many progressive utilities, Delaware Power & Light Company selected Richardson Automatic Coal Scales to maintain a constant check on boiler efficiency in their new generating station. The bank of Richardson Model 39's shown now handles this responsibility.**

**To both industrial and utility power generating stations, specifying Richardson means—**

1. A 24" x 24" inlet opening and 26" wide belt for maximum coal flowability.
2. All wiring and controls outside coal chamber.
3. Access doors which will not spill dust on floor when opened.
4. Beam ratio test facilities outside coal chamber.
5. Gravity operated by-pass, with no restriction of coal flow to downspout.
6. No drag links or wires attached to weigh hopper.
7. Nationwide after-delivery service.

**Latest development in the 39 Series of Richardson Automatic Coal Scales is the Model H-39 shown below. May we send you our new 16-page engineering data book on the H-39 Coal Scale (Bulletin 0352), without cost or obligation?**



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**Richardson**

MATERIALS HANDLING BY WEIGHT SINCE 1902


cal and chemical data on these materials, assembled in an easy-to-find style and augmented by lists of applications.

### Power Piping

The specific services and facilities such as stress analyses, metallurgical research, welding methods, special heat-treating techniques available at the Fabricated Products Div. of the M. W. Kellogg Co. make up the subject matter of a 12-page booklet, "For the Modern Central Power Station." A step-by-step picture story from joint positioning to final induction heat treatment is provided for power piping welding.

### Boiler Refractories

A 20-page bulletin, R-36, of the Babcock & Wilcox Co. provides operators with a guide to selecting refractories for boilers. Typical uses of firebrick, insulating firebrick, castables, plastics and motors, in both refractory-lined and watercooled boilers are described. A separate section covers ash pit.

### Duplex Steam Pump

The 4-page bulletin 230 explains the advantages of the Warren Steam Pump Co. horizontal duplex steam pump with piston valve steam chart. Sectional and exterior views are given as well as specifications and dimensions.

### Induced Draft Fans

Packaged units including fan, motor, motor base and adjustable speed V-belt drives are described for the Chicago Blower Corp "Spud" fans in the recently released Bulletin SI-101.

### Residual Fuel Oils

The 8-page bulletin, No. 1601, of the Preferred Utilities Mfg. Corp. discusses ways and means of heating and handling heavy fuel oils for use in burners of boilers, furnaces. Details are furnished on tank structures, suction and return lines, addition of heating coils as well as the manufacturer's specific recommendations.

### Safety Valves

Complete design information, data on saturated steam capacities, correction factors for superheat and valve material specifications for the manufacturer's HC safety valve are supplied in a 16-page brochure now available from the Crosby Steam Gage & Valve Co.

### Centrifugal Pumps

The 12-page bulletin G-1 released by the La Bour Co. features data and details on the company's packingless self-priming centrifugal pumps, type CG, for both flooded suction and suction lift operations.

# Engineers Joint Council Holds First General Assembly

Engineers Joint Council, constituted of eight major national engineering organizations with a total membership of 170,000, held on Jan. 21, 1955 in New York its first General Assembly, a day-long program of presentations and discussions.

The attendance, approaching 400, represented not only the constituent organizations, but also many of the nation's leaders in engineering, science and industry. In the panels and forums the Government was represented by several spokesmen.

The General Assembly served as an occasion for further announcement of details of the Nuclear Congress to be held, under EJC sponsorship and with the participation of other organizations, Dec. 12–16, 1955, in Cleveland. The broad scope of this convention was related by **Dr. John R. Dunning,** General Chairman of the EJC Committee on Nuclear Engineering and Science, Dean of the School of Engineering, Columbia University, and by **Dr. Donald L. Katz,** Program Chairman for the Nuclear Congress, Chairman of the Department of Chemical and Metallurgical Engineering, University of Michigan.

In a discussion of "Engineering Changes Introduced by Atomic Energy," **Miles C. Leverett,** Engineering Manager, Aircraft Nuclear Propulsion, General Electric Co., Cincinnati, emphasized that there has been "brought about an increasing awareness of the value of good fundamental training, of the value of engineers sufficiently broad in outlook and sufficiently flexible so that they can think and operate effectively in a number of technical fields.

"People with such characteristics and training are not commonly found. In my experience, it has proved feasible and desirable to create such people by intentionally throwing carefully selected mechanical, chemical and electrical engineers into the heart of our reactor physics activities for six months to two years.

"Another striking feature of the nuclear engineer's position is that his opportunity for advancement is great. One person in six in the nuclear energy industry is primarily technical in background or function. The industry at present is and probably will be for some time dominated by considerations of technical feasibility. Only recently has the more usual dominance of cost considerations come to play an important part. This tends to give the technically trained person an unusually large share in the direction and management of the over-all enterprise.

"One very noticeable characteristic of the nuclear energy industry is its growing similarity to the aircraft industry. In both cases the Federal Government is the primary customer. Both industries are dominated primarily by military considerations. Both have a high percentage of technical content. There is a considerable amount of government ownership of production facilities, and so on.

"The nuclear engineer who wishes to get some indication of the future would do well to look at the aviation industry. If he can expect that his professional experience will parallel that of the aeronautical engineer he has, indeed, a most exciting and productive future."

The banquet speaker, **Donald A. Quarles,** Assistant Secretary of Defense, in Research and Development, took up the subject of "Engineers and Our National Well Being."

"Perhaps the most important thing the Communists have done has been to modernize their educational system and to orient it strongly toward the physical sciences and industrial technology. They have increased their scientific and technological potential by an order of magnitude. They are turning out engineers and scientists at more than twice the rate in this country. If current trends continue, it will be a matter of only a few years before their scientific and technical manpower exceeds ours.

"This is not to imply that even with such numbers they would have a stronger technological base then we, since this depends on many things besides numbers. We still would have the stronger and more virile industrial system. There is no question in my mind about our ability to stay ahead in this technological race. In the military field however, it is clear we are competing with a single-mindedness of purpose and a ruthless concentration on the aims of militant Communism that constitute a serious challenge to our way of life in the free world.

"It is important for us to work toward national policies that enhance and conserve engineering manpower. There are good policy reasons for insisting no young man escape the sacrifice other young men must make in military service. On the other hand, engineers are scarce. If we are to sustain a program that will keep us ahead in the technological race, our need for engineers and scientists must be expected to increase.

"This is a problem we must deal with on a strictly national-interest basis. If we are to win this race, our manpower must be disposed to our greatest national advantage. The military services require some specialists in the performance of their missions. Beyond this, we cannot afford to put engineers and scientists into uniforms.

"This great concentration of our scientific and technological resources on defense problems is not only justified but necessitated by the world situation. To do less would jeopardize our position of technological superiority so essential to our long-term security. On the other hand, to attempt to use directly on defense projects a bigger proportion of our total potential might be unwise as a long-term program, particularly when one considers the interdependence of the military and civilian fields.

"On the one hand it is apparent that, if we really believe in free enterprise and in getting the government out of all business activities except those necessary in the public interest and that cannot be properly performed by private enterprise, then the time certainly has come to start getting the government out of the atomic power business.

"On the other hand, there are plausible arguments that the people's money has been spent to develop the art and to produce fissionable or nuclear fuel and operate the power plants 'for the people.' Of course, the hitch in this argument is the hidden premise that government operation of such power systems would be in the best interest of the people. I, at least, believe it would not and, therefore, I take great satisfaction in the enactment of the Cole-Hickenlooper Act which, while not prescribing government operation, wisely provided for an orderly transition to private ownership and operation of nuclear power facilities."

Engineering manpower and the history and activities of the Engineering Manpower Commission of EJC were major subjects of the General Assembly. The luncheon speaker, **Dr. Dael Wolfle,** Administrative Secretary of the American Assn. for the Advancement of Science, Washington, D. C., advised that substantial relief of the shortage of engineers, scientists and other professionals could be achieved by a determined effort to induce qualified high school graduates to proceed to college.

"There is a supply which is not

now being developed. It consists of bright high school graduates who do not go to college. If arrangements could be made to get that group through college, the number of average or better college students could be doubled. The problem is partly economic. Many bright boys and girls do not have the money a college education would require. But, even more, the problem is social. Many bright boys and girls grow up without ever having been interested in developing and using their superior abilities."

At the forum discussions on engineering manpower, **Dr. Thomas H. Chilton,** Technical Director, E.I. du-Pont de Nemours & Co., Past President, AIChE, was Chairman. Participants included **Solomon C. Hollister,** Dean of the Cornell College of Engineering; **M. H. Trytten,** Director, Office of Scientific Personnel, National Research Council and consultant to Engineering Manpower Commission; **Carlton S. Dargusch,** consultant to EMC; **James M. Mitchell,** Deputy Assistant Secretary of Defense, Manpower Personnel; **Norman A. Shepard,** Chemical Director, American Cyanamid Co.; **Howard A. Meyerhoff,** Executive Director, Scientific Manpower Commission; and **Commander Carrison,** of the Navy.

In opening the panel and discussion on "Employment Conditions and Unionization—Their Effect on the Engineer," **G. Brooks Earnest,** Chairman, made a revealing report on a questionnaire submitted to the members by ASCE, ASME and AIEE, which have a total membership of 127,000. Dr. Earnest, who is President of Fenn College, Cleveland, and Past Vice President of ASCE, said the results were being presented for the first time. Of the 112,225 questionnaires mailed (certain membership classifications were not included), 64,206, or 57% responded. Mr. Earnest said:

"Of the 64,206, only 2,348, or about 3.7% were actually members of an established collective bargaining group. However, 17,318, or 27%, reported as not being opposed to collective bargaining. Furthermore, 12,833, or 20%, reported they believed collective bargaining would be advantageous to them. Of 8,199 reporting from two member societies in this category (the third did not ask the question), 347, or about 0.9% would prefer to be represented by a craft or labor union.

"It is important to note that 45,992, or 72% of the 64,206 returns opposed collective bargaining for professional engineers and that 42,314, or 66%, felt collective bargaining is incompatible with professional status.

"The results of the questionnaries from these three societies present a challenge to the engineering profession. We do not know the thinking of the remaining 43% of the 112,225 members polled who did not respond. But, assuming it might approximate the thinking of the 57% responding, there then would be 31,500 members who are not opposed to collective bargaining for professional engineers. We are charged with the responsibility of first converting 31,500 of our own members to the true professional status category.

"These percentages, resulting from questionnaires to members of three constituent societies of EJC, 'point up' the missionary work ahead of us in spite of the permissive clauses in the Taft-Hartley Act."

On the question, "Is collective bargaining compatible with professionalism?" an emphatic negative was voiced by **Dean Nathan W. Dougherty,** of the College of Engineering, University of Tennessee, member of the EJC Committee on Employment Conditions.

"Bargaining groups cannot grow


EXTRA YEARS

OF MORE DEPENDABLE POWER

and at less cost per pound of steam

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For insertion into pipe

FOR EVERY APPLICATION

BRONZE, IRON, STEEL, STAINLESS STEEL

FIG. 39 Cylinder with Impeller

FIG. 17-28 Cylinder

FIG. 215 Flanged

FIG. E-37 Double Window

FIG. 212 Visibility Welding Neck or Screw

FIG. E-811 Flapper

FIG. E-1810 Rotating Wheel Type

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into unity groups or professional associations," reminded Dean Dougherty. "They are committed to the concept of jurisdictions rather than performance with requisite knowledge and skill. They must emphasize seniority to hold their membership and strength. Jurisdictions and seniority are in direct conflict with the concept that ability must be recognized and given first place. To a professional, the sole criterion of the work he must do is his ability to perform with needed knowledge and responsibility. . . . When working conditions are determined by group action the very nature of professionalism is violated. . . . Why should a professional have to turn to collectivism to get a salary raise? If such conditions exist it is because professionals in management are not assuming their responsibility. . . . Any connection or pressure from management or fellow workers which tends to reduce the engineer's freedom to make judgments is a menace to his status and harmful to his position."

The figures reported by Chairman Earnest moved **E. Lawrence Chandler,** Assistant Secretary of ASCE and Treasurer of EJC, to comment: "Even though only a little more than 3% of the membership of the three societies are members of unions, we are challenged by the circumstances that so many express a favorable reaction in spite of the fact that the essence of collective bargaining is so foreign to the basic concept of professionalism and to the fundamental thinking inherent in creative engineering."

**Arthur K. Doolittle,** Assistant Director of Research, Carbide & Carbon Chemical Corp., and Vice President, AIChE, spoke on "Engineering—A Profession."

**Carlton S. Proctor,** of New York, Past President, ASCE, former Vice President, EJC, was Chairman of a panel on "Service Opportunities for Engineers Joint Council." Other participants included **Clarence E. Davies,** Secretary, ASME, and **Dr. Harold S. Osborne,** of Montclair, N. J., Past President, AIEE. Postwar guidance to the government by EJC on German and Japanese economic aspects and the extensive efforts of EJC in the national water policy field were among the many works of the organization reviewed.

At the annual meeting of EJC, held the evening before the General Assembly, **Dr. Saville** was named President for a second term. **Edgar J. Kates,** of New York, became Vice President. **E. L. Chandler,** of New York, is Treasurer. **Brig. Gen. Stewart E. Reimel** (ret.), of Washington, is Secretary, and **E. P. Lange,** of New York is Assistant Secretary.

200-1

FOR WANT OF A NAIL...

*Something that wasn't there once cost a king his life.*

For today's boiler, lack of internal protective surfacing is hardly a life or death matter. Yet consulting engineers . . . insurance underwriters . . . power plant operators increasingly specify, recommend, and purchase Apexior Number 1 for tube and drum coating. Why?

Because the yardstick of return on investment proves Apexior's unique service *now pays off at the highest rate ever* . . . for modern boiler design and operation today permit a single Apexior application to deliver maximum protection not only for a normally anticipated five years, but for one — three — sometimes even *five years more!*

And because Apexiorizing is now a one-coat procedure, former material and labor estimates are halved. Protection that can last twice as long today costs *half as much* . . . a trifling pennies-per-square-foot premium to insure full return on a major capital investment.

Like the legendary nail, boiler protective coating may seem a factor of small significance — yet it can mean the difference between acceptable performance and the best of which the modern boiler is capable. The assurance every inspection gives that tubes and drums are functioning at new-metal peak efficiency is the measure of Apexior's service in maintaining highest steam production reliability and quality — a contribution measured ultimately in profit dollars.

*Internal boiler protection is but one phase of Dampney corrosion-control activity. Dampney Coating Systems for specified end-use service protect cooling towers — intake water structures — pipeline interiors. For a recommendation to meet your requirements, write*

MAINTENANCE FOR METAL

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REFRACTORY CEMENT

- BONDS STRONGER
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*For Example-*

**On Induced Draft Fan Casings**—Where previously repairs required heavy, abrasion-resistant steel plates, now a coating of Super #3000 provides safe protection for many months against the scouring action of fly ash.

**On Inside Duct Lining**—A ¾" thick layer of Super #3000 over the insulation provides long-life refractory lining that withstands erosion of hot abrasive gases.

**On Boiler Tubes**—By painting the tubes (in the second and fourth pass of the boiler) with a thin mix of Super #3000, considerable protection is provided against erosion. This large public utility now does this work on all its boilers.

There are a great many more reports of Super #3000 success—where other refractory mortars have failed quickly and utterly—in boiler walls and arches, coke oven floors, furnace linings, etc.

Users call it the "Wonder Cement." Try it—you'll agree.

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REFRACTORY BONDING AND CASTABLE CEMENTS
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## Business Notes

Robert S. Swain, Executive vice-president of **Pantex Manufacturing Corp.,** Pawtucket, R. I., has announced the acquisition by Pantex of the **Livingstone Engineering Co.,** Worcester, Mass., manufacturer of Speedylectric Boilers.

Metallurgists at the Research Laboratories of **Westinghouse Electric Corp.** are conducting tensile tests on metals at temperatures as low as minus 452 F. The metal specimens are stressed within a specially designed chamber which has been cooled with liquid helium. Results of these tests will provide engineers with needed information regarding types of metals that are best suited for use under extreme temperature ranges.

Lewis L. Strauss, chairman of the **Atomic Energy Commission,** recently announced the AEC has approved a proposal by the **Consumers Public Power District** of Columbus, Neb., to undertake a nuclear power study under AEC's Industrial Participation Program.

Formation of an industry application section headed by B. G. Witty has been announced by R. M. Casper, manager of the power department of **Allis-Chalmers Mfg. Co.,** general machinery division with T. B. Montgomery as chief engineer of the section. The section will have the responsibility of processing inquiries, handling commercial matters and application engineering of general machinery division products normally sold to industry as a related operating group of equipment.

Members of the technical advisory committee for the **World Symposium on Applied Solar Energy,** to be held in Phoenix November 2–5, were recently announced by Lewis W. Douglas, general chairman of the symposium. Among those named were: Dr. Charles G. Abbot, research associate at the **Smithsonian Institution,** Washington, D. C.; Dr. Vannevar Bush, president of the **Carnegie Institution of Washington;** Dr. Godfrey Lowell Cabot, chairman of the board of **Godfrey L. Cabot, Inc.,** Boston, Mass.; Dr. Farrington Daniels, chairman of the Department of Chemistry, **University of Wisconsin;** Dr. Lawrence J. Heidt, associate professor of physical chemistry and Hoyt C. Hottell, director of Fuel Research Laboratory, both at **Massachusetts Institute of Technology.**

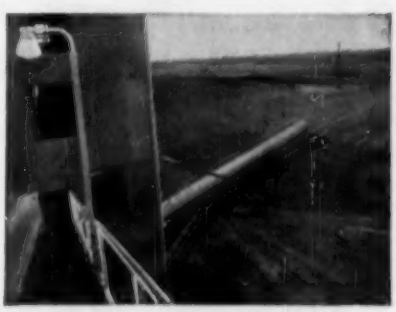
**The Superheater Co., Ltd.,** Montreal, Can. has changed its name to **Combustion Engineering-Superheater Ltd.,** effective December 23, 1954.

General View—Saybrooke Station
Central Illinois Elec. & Gas Co.
Stone and Webster Eng. Corp.
Consulting Engineers

# Bartlett-Snow coal handling at Rockford

● The illustration above shows the first 30,000 KW unit of a plant which is to be extended into a 110,000 KW station. All coal handling equipment including track hopper and grill, duplex feeder, conveyors, galleries, chutes, tripper and all supporting structures were fabricated in our shops, and installed by us, to Stone and Webster's plans. For efficiency, satisfaction, and fixed unit responsibility, let the Bartlett-Snow coal handling engineers, with their long experience and complete facilities work with you on your next job.

Belt Conveyor from
Track Hopper to Crusher House



View of Crusher House and
Stocking Out Conveyor

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*"Builders of Equipment for People You Know"*

# BAYER
# STEPS UP BOILER PERFORMANCE

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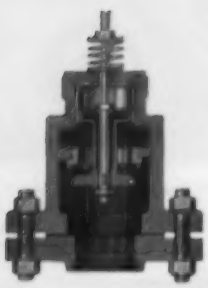


*Bayer Balanced Valves are famous for their long life and continued tightness.*

*Bayer Single Chain Balanced Valve Soot Cleaner.*

WITH THE Bayer Balanced Valve Soot Cleaner the balancing chamber above the piston disc impounds steam when the valve closes, thus relieving valve parts from shock. The valves remain ***steam tight*** because the dashpot action causes the valve to seat gently. Unbalanced valves close with a hammer stroke and soon become leaky.

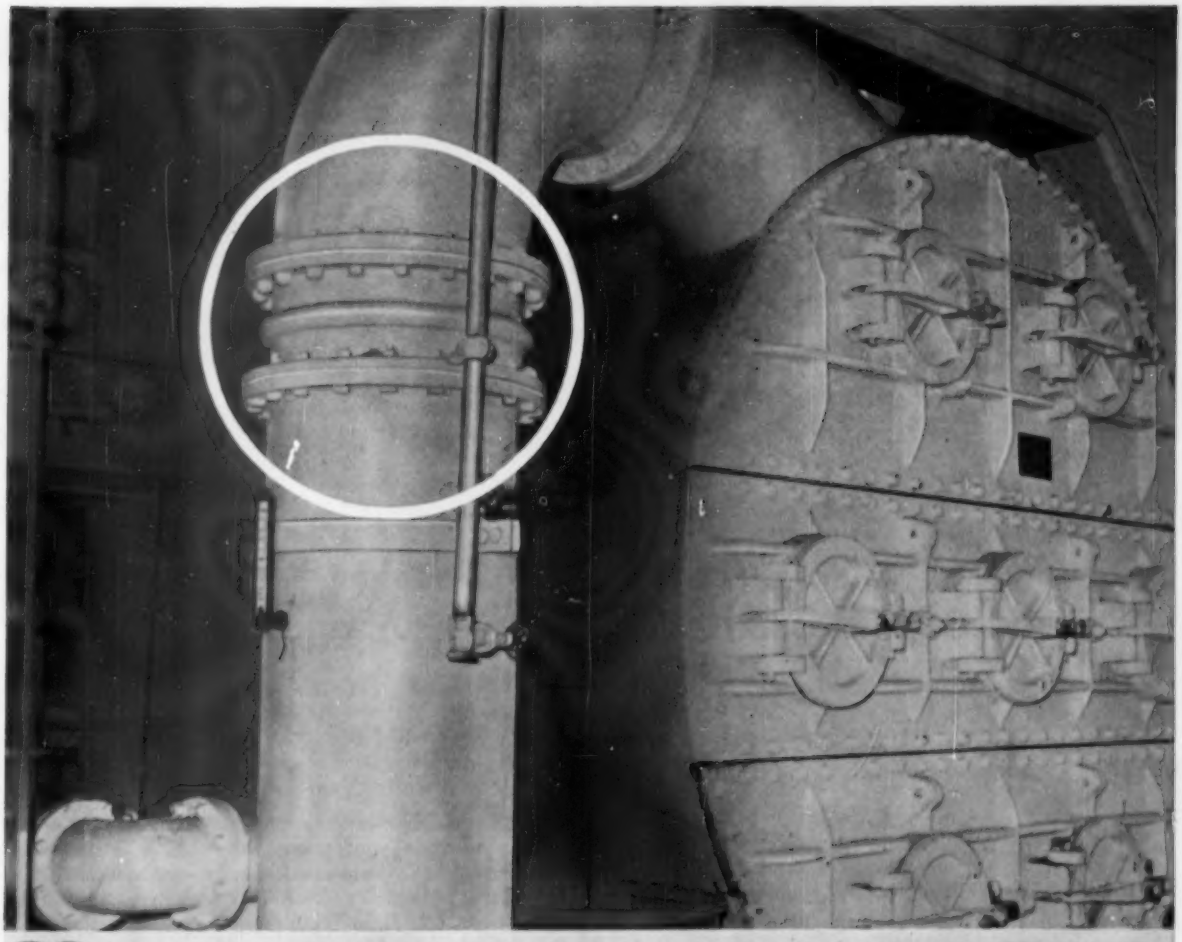
When stationary elements are used the Bayer stationary balanced valve head may be furnished. Thus all the cleaning elements of the entire soot cleaner system can be controlled by the Bayer quick-opening Balanced valves. This gives a uniform or standard valve controlled system and in addition, when high pressures require a reduction in pressure *at each individual element* this Balanced valve unit, whether used with a stationary or a revolving element, can be fitted with an integral orifice plate valve.

Piping connections can be kept in the same plane and undesirable bends or fittings avoided when the Bayer Balanced Valve is installed with both stationary and revolving elements.

Valve parts are standard and interchangeable and when high pressure heads are fitted with orifice plate regulating valves these parts are also interchangeable.

## THE BAYER COMPANY

**SAINT LOUIS, MISSOURI, U. S. A.**



**30-YEAR SERVICE RECORD CHALKED UP BY U. S. EXPANSION JOINTS IN WEST COAST POWER PLANT**

Above is one of 12 U.S. Expansion Joints installed 30 years ago in a California utility plant. Despite their age these joints are still functioning.

U.S. Rubber Expansion Joints are economical, flexible connections used in pipe lines to take up the stresses due to vibration, expansion and contraction. They prevent the transmission of noise, and take care of misalignment. They have no moving parts to wear or bind and thereby shorten service life.

U.S. Rubber Expansion Joints can be installed on both new and old piping and equipment. These joints plus engineering service are available through any of our 27 "U.S." District Sales Offices, or write address below.

*"U.S." Research perfects it...*
*"U.S." Production builds it...*
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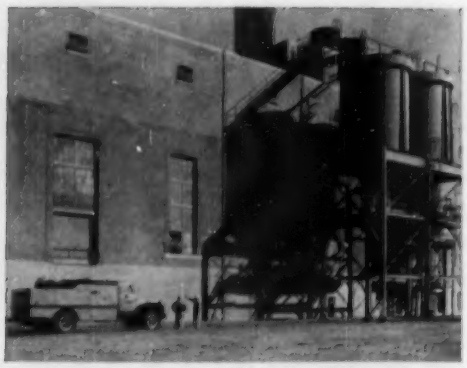
Hose • Belting • Expansion Joints • Rubber-to-metal Products • Oil Field Specialties • Plastic Pipe and Fittings • Grinding Wheels • Packings • Tapes • Molded and Extruded Rubber and Plastic Products • Protective Linings and Coatings • Conductive Rubber • Adhesives • Roll Coverings • Matts and Matting

# 300,000 PPH BOILER CLEANED CHEMICALLY IN ONE DAY!



Dowell engineers bring solvents to the job in truck-mounted tanks, along with all pumping and control equipment. They apply the chemicals as necessary—by filling, spraying, jetting, cascading or vaporizing.

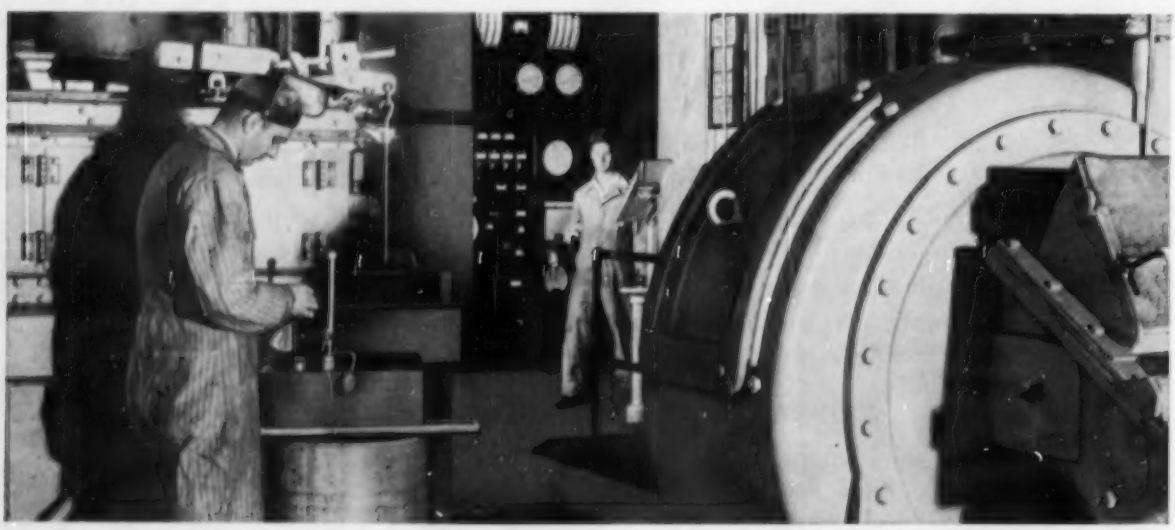
## Comparative cases showed DOWELL cleaning took less time . . . removed more scale than mechanical methods

This is a case history on a 300,000 pound per hour boiler in a refinery. A routine inspection showed that iron oxide and silicate scale fouled the tubes. Dowell engineers cleaned the boiler with chemical solvents in less than 22 hours.

Dowell chemical cleaning is the standard method of removing deposits from boilers in this plant. Comparative tests showed that the chemical method was both faster and more thorough than the mechanical means previously used. The operator was surprised at the relatively large amounts of scale and sludge removed by chemical cleaning. Dowell has cleaned 25 of the 27 boilers in this plant. Several have been cleaned as many as three times on an annual basis.

Dowell liquid solvents go wherever steam and water flow, reaching surfaces inaccessible to other methods. No special scaffolding is required. *Dismantling and down-time are kept to a minimum.* Often, equipment may be cleaned while in operation.

Perhaps chemical cleaning could improve the efficiency of equipment in your plant—for example, heat exchangers, piping systems, tanks and process towers. For complete information and estimates, call the nearest of more than 130 Dowell offices, or write directly to Dept. D-25, DOWELL INCORPORATED, TULSA 1, OKLAHOMA.



*chemical cleaning service for industry*

DOWELL

A SERVICE SUBSIDIARY OF THE DOW CHEMICAL COMPANY

# Trying to reduce piston packing maintenance?

**J-M Pump Cups** after removal from feed water pumps at Morgan Laundry. Set above consists of 2 J-M "A" Cups with spacer and 2 followers, mounted on pump rod

**At the Morgan Laundry, J-M Moulded Packings provide**

## "8 times longer life– replacement in 1/6 the time"

THE MORGAN LAUNDRY, large supplier to hotels and institutions, requires dependable, trouble-free service from boiler room equipment. In their New York City plant, the Engineering Department found that conventional piston packings for boiler water feed pumps lasted only a relatively short time. Many hours of down time were required to replace packings. Liner wear became progressively worse.

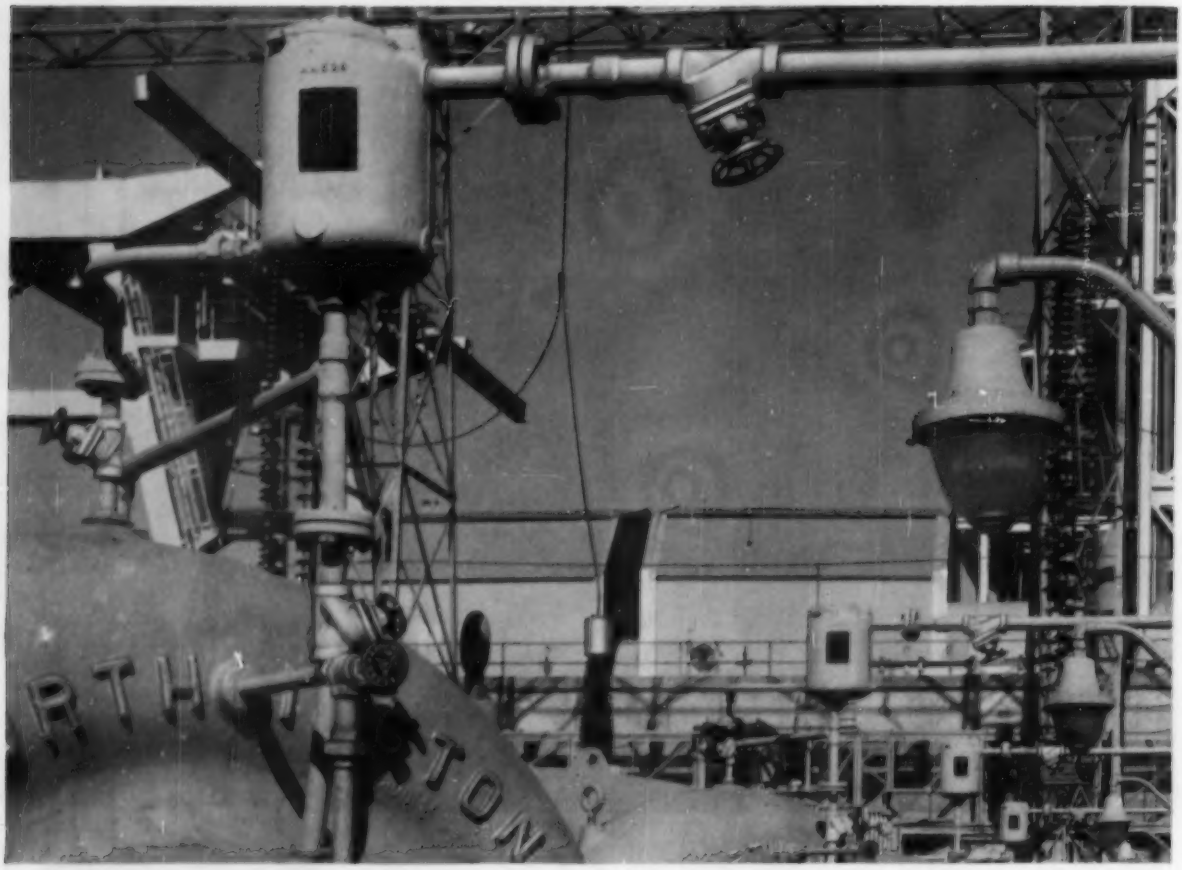
When the Engineering Department changed from the conventional material to J-M Moulded Packing Cups, service life of the packing was increased more than 8 times. Liner wear was greatly reduced. Replacement with the new packings was made in 1/6 the time. Packings could be easily installed for proper service, without special skill or experience. Satisfaction with this application has led to the use of J-M Moulded Packing Cups on other boiler room equipment and on presses in the Morgan Laundry plant.

These precision moulded packings offer definite advantages over conventional types. Because they form a highly efficient seal, they contribute to improved performance, lower operating and maintenance costs. For steam pump pistons, they are available in sets consisting of two cups and two followers, with a spacer. This pump cup set, J-M Style 80, is similar to that shown in the illustration above.

**Your Johns-Manville Packings Distributor** can help you make the right selection for your application, from Johns-Manville's line of custom-made Piston Packing Cups. For complete details write him or Johns-Manville, Box 60, New York City 16. In Canada, 199 Bay Street, Toronto 1, Ontario.

JOHNS-MANVILLE JM PRODUCTS

**Johns-Manville PACKINGS & GASKETS**



# Corrosive circulating water tamed here by these CRANE VALVES

**THE CASE HISTORY**—Almost 2 years' operation without any maintenance of valves on circulating water lines to condensers, and on priming and instrumentation systems—with no trouble in sight. That's the experience of Southern California Edison Company's 280,000 k.w. steam station at Etiwanda with Crane Packless Diaphragm Valves.

The plant's engineers knew that sediment in recirculated water would quickly cut out the seats in ordinary valves and its corrosive elements would attack working parts to make valve operation difficult.

Not so with Crane Packless Diaphragm Valves. Their sealed bonnet keeps working parts out of contact with line fluid—free of corrosive effects. Separate disc construction with pliable insert resists erosion—seats tightly even on foreign particles. Large or small, these valves operate easily with fewer turns to the cycle. Typical Crane quality throughout—they're made better to do the job better—a bigger value for the thrifty buyer.

**CRANE No. 1610 PACKLESS DIAPHRAGM VALVES**

No packing to maintain. Neoprene diaphragm has longer life because it seals the bonnet only—is not subject to the cutting and crushing encountered when also required to do the seating. Separate disc gives control of fluid even should diaphragm fail. Wide selection of materials and sizes. Write for folder AD-1942 or see your Crane Representative.

# CRANE CO.

*General Offices:* 836 S. Michigan Ave., Chicago 5, Illinois
*Branches and Wholesalers Serving All Industrial Areas*

**VALVES • FITTINGS • PIPE • KITCHENS • PLUMBING • HEATING**

**CRANE'S FIRST CENTURY . . . 1855-1955**

# 8 "BUFFALO" INDUCED DRAFT FANS =2,800,000 LBS/HR OF POWER-PRODUCING STEAM

The eight "Buffalo" Induced Draft Fans above serve the four reheat cycle steam generators of the 400,000-kw Wabash River Station of the Public Service Company of Indiana, Inc., above, right. It takes a lot of air to produce power — and the source of air must be as reliable as the fuel. This is why "Buffalo" is the choice for the punishing induced draft job in so many utility stations as well as in industrial power plants. Write for Bulletin 3750 and see why "Buffalo" Forced Draft, Induced Draft, Gas Recirculating and Primary Air Fans give the dependable air delivery your boilers need for top output!

"Buffalo"

**BUFFALO FORGE COMPANY**
170 MORTIMER ST. BUFFALO, NEW YORK
*PUBLISHERS OF "FAN ENGINEERING" HANDBOOK*
Canadian Blower & Forge Co., Ltd., Kitchener, Ont.
*Sales Representatives in all Principal Cities*

VENTILATING AIR CLEANING AIR TEMPERING INDUCED DRAFT EXHAUSTING FORCED DRAFT COOLING HEATING PRESSURE BLOWING

Another Beaumont Birch Ash Handling Installation

Discharge end section of a flooded hopper for Beaumont hydraulic system showing rugged supporting structure and circular protected observation ports of special heat resistant glass.

# Why BEAUMONT BIRCH Hydraulic Ash Handling Systems Assure You

## *Reliable, Efficient Service*

In every detail of Beaumont Hydraulic Ash Handling Systems, you'll find they're designed for practical considerations of boiler efficiency, operating safety, minimum man-hour attention and minimum maintenance.

For example, on flooded hoppers beneath pulverized coal fired boilers, costly shut downs are never necessary when water jet nozzles in the ash hopper require replacing. They are easily and safely replaced *while the boiler is in operation* . . . the rugged sluice gate and operating cylinder are mounted on a single casting, completely shop assembled. This assures perfect alignment of cylinder for long uninterrupted service.

On flooded hoppers, operators are always protected at observation ports by special glass resistant to thermal shock, in addition to a protecting metal guard. Built-in spray washers keep all observation ports clean and free from dirt and fog.

These and many other points, such as, sluiceways, sumps, dewatering bins, flyash handling systems and other supplemental equipment are only a small part of the attention to details that are characteristic of Beaumont Birch Systems.

Power and Consulting Engineers specify Beaumont Birch Hydraulic Ash Handling Equipment because they are assured of design, engineering and construction to exacting specifications!

Beaumont's background of over fifty years in the design and manufacture of ash handling systems gives you long service life with a minimum of maintenance.

For complete details of the many efficiency and economy features of Beaumont Hydraulic Ash Handling Systems, call in a Beaumont Birch engineer or write direct.

Beaumont BIRCH COMPANY

1506 RACE STREET, PHILADELPHIA 2, PA.

DESIGNERS — MANUFACTURERS — BULK MATERIAL HANDLING SYSTEMS


## Advertisers' Index


Aerotec Corporation, The..... *
Air Preheater Corporation, The 26
Allis-Chalmers Mfg. Company, Tractor Division.....12 and 13
American Blower Corporation. .....14 and 15
American Brake Shoe Company..... 87
Armstrong Machine Works.... 28

Bailey Meter Company..... 32
Baltimore & Ohio Railroad.... *
Barrows Porcelain Enamel Co. 70
C. O. Bartlett & Snow Company, The..... 79
Bayer Company, The..... 80
Beaumont Birch Company.... 86
Belco Industrial Equipment Division, Inc..... *
Blax-Knox Company, Construction Equipment Div.... 61
Buell Engineering Company, Inc..... 23
Buffalo Forge Company..... 85

Cambridge Instrument Company..... *
Carborundum Company, The. 37
Chain Belt Company..... 88
Chesapeake & Ohio Railway.. *
Clarage Fan Company..... *
Cochrane Corporation..... *
Coen Company..... 36
Combustion Control Division, Electronics Corporation of America.....20 and 21
Combustion Engineering, Inc. .....Second Cover, 16 and 17
Combustion Publishing Company, Inc..... 50
Copes-Vulcan Division, Continental Foundry & Machine Company.....30 and 31
Crane Co..... 84

Dampney Company, The..... 77
Dearborn Chemical Company. .....24 and 25
De Laval Steam Turbine Company..... *
Diamond Power Specialty Corporation.....Third Cover
Dowell Incorporated..... 82

Eastern Gas & Fuel Associates *
Economy Pumps, Inc..... *
Edward Valves, Inc..... *
Engineer Company, The..... 71
Enos Coal Mining Company, The..... *
Ernst Water Column & Gage Company.....70 and 76
Euclid Division, General Motors Corporation..... *

Fairmont Coal Bureau..... 71
Flexitallic Gasket Company... 40
Foster Engineering Company.. *

General Electric Company.... *
Gerotor May Corporation..... 69
Gifford-Wood Co..... 34
Graver Water Conditioning Company..... 18


(*Continued on page 87*)

Green Fuel Economizer Company, Inc..... *
Grinnell Company, Inc..... *

Hagan Corporation .....8 and 9
Hall Laboratories, Inc..... 38
Haskins-Turner Co..... 56
Hays Corporation, The...4 and 19

Ingersoll-Rand Company..... *

Johns-Manville..... 83

M. W. Kellogg Company, The 10
Koppers Company, Inc..... *

Lukens Steel Company..... 2
Lummus Company, The..... *

Manning, Maxwell & Moore, Inc..... *
W. K. Mitchell & Company, Inc..... 29

National Airoil Burner Co., Inc..... *
National Aluminate Corporation..... 35
National Coal Association..... 27

Old Ben Coal Corporation.... *
Olin Mathieson Chemical Corporation..... 33

Pacific Pumps, Inc..... *
Peabody Engineering Corporation..... *
Pittsburgh Piping & Equipment Company..... *
Poole Foundry & Machine Company..... 61
Powell Valves..... *
Prat-Daniel Corporation..... *

Radio Corporation of America 5
Refractory & Insulation Corporation..... 78
Reliance Gauge Column Company, The..... 72
Republic Flow Meters Company..... *
Research-Cottrell, Inc..... 6
Richardson Scale Company... 74

Benjamin F. Shaw Company.. .....Fourth Cover
Standard Tube Company, The *
Stock Equipment Company... 39

W. A. Taylor and Co..... 73
Thermix Corporation, The.... 3
Todd Shipyards Corp., Combustion Equipment Div..... 76

United States Rubber Company..... 81

Walworth Company..... 22
Western Precipitation Corporation..... *
Westinghouse Electric Corporation, Sturtevant Division 11
C. H. Wheeler Manufacturing Company..... *
L. J. Wing Mfg. Company..... *

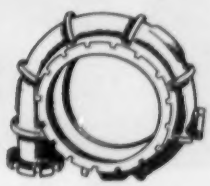
Yarnall-Waring Company..... 7

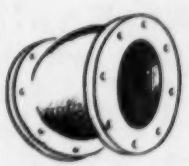


# ABK METAL CASTINGS

## INCREASE SERVICE LIFE

***when used in wet or dry ash handling equipment***





In coal-fired stations where proper handling of abrasive ash can save dollars, no better material can be used than ABK Metal.

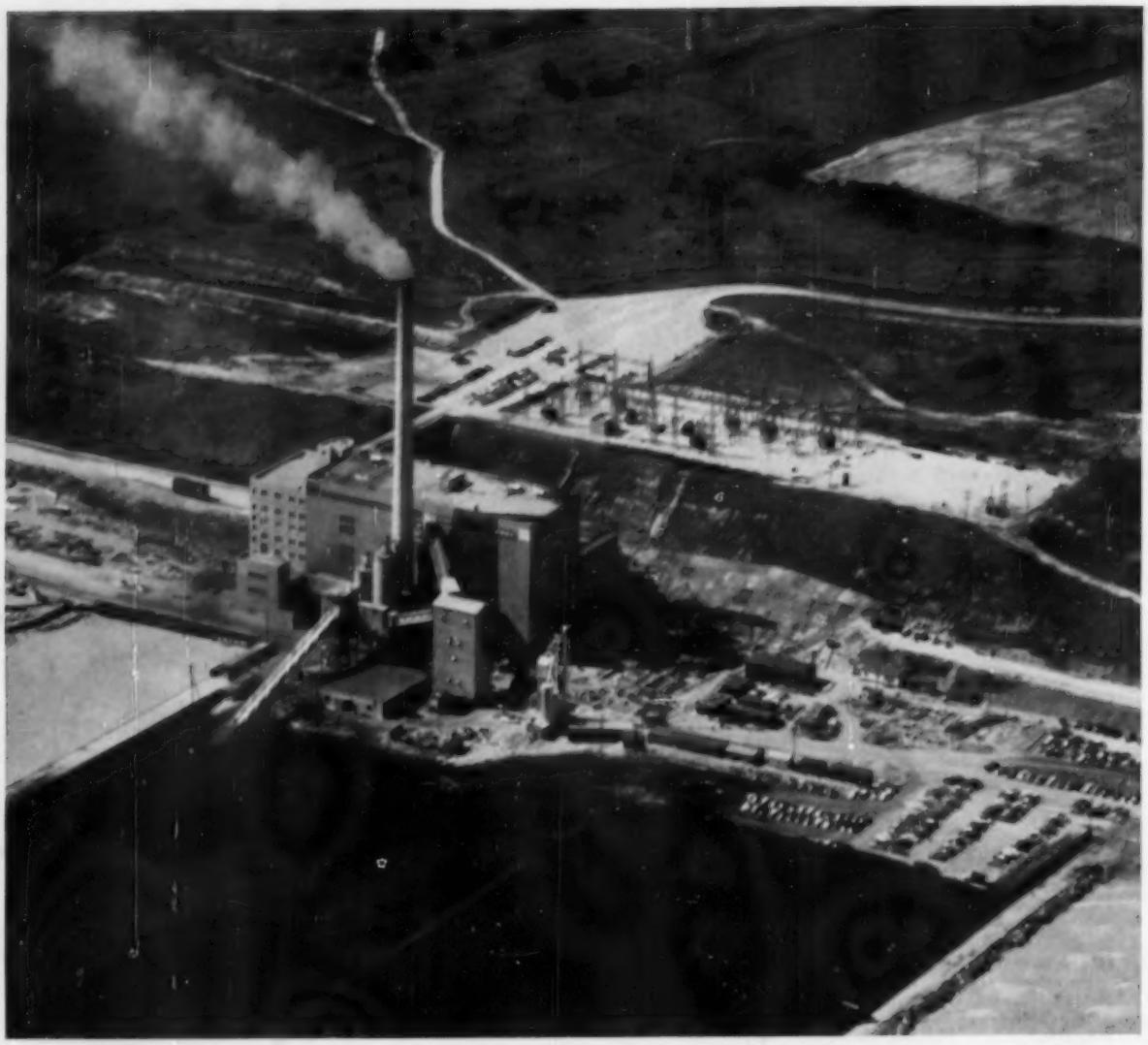
That's because castings of ABK Metal minimize the destructive wear of abrasive ash and clinker. The controlled structure of this hard nickel-chrome iron (500 to 700 Brinell) means that each unit lasts 4 or 5 times as long as white irons with approximately the same Brinell value in the same service . . . thus reducing downtime and cutting maintenance costs.

Don't let abrasion steal your operating dollars. The next time you have to replace pump casings or impellers, pipes, fittings, liners, or other parts subjected to wet or dry ash abrasion, specify castings in ABK Metal—a Brake Shoe exclusive.

*Write Dept. A for Brake Shoe's information folder on ABK Metal Castings.*

AMERICAN Brake Shoe COMPANY

BRAKE SHOE AND CASTINGS DIVISION
230 Park Avenue, New York 17, N. Y.



## OAK CREEK STATION • *Wisconsin Electric Power Company*
## An Engineering Triumph in Efficient Power Station Planning

Oak Creek Station stands as a tribute to the outstanding planning of Wisconsin Electric Power Company's own engineering staff. It is, indeed, significant that Rex® Equipment was selected for the big coal-handling job in producing 240,000 k.w. capacity.

CHAIN Belt Company Engineers were called upon to assist in developing a dependable, trouble-free coal-conveying system that would easily take care of future station capacity expansion.* The result: typical of what you can expect with help from CHAIN Belt technicians.

When planning a new coal-handling layout or considering the modernization of your present system, you, too, can benefit from the experience and specialized skills of CHAIN Belt Conveying Engineers and the top performance of Rex quality coal-handling equipment. Just contact your nearest CHAIN Belt District Sales Office or write to CHAIN Belt Company, 4784 W. Greenfield Ave., Milwaukee 1, Wisconsin.

*An additional 120,000 k.w. capacity is planned for this year.

**CHAIN BELT COMPANY**

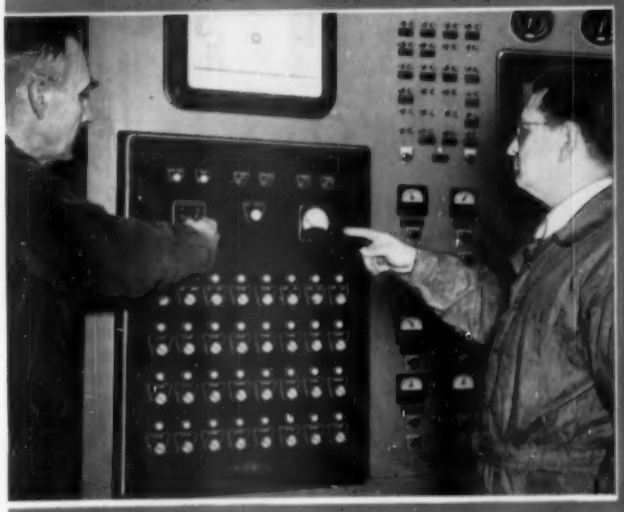
District Sales Offices in principal cities

# DIAMOND SERVICE POLICY

## *Improves*

## BOILER CLEANING AND SAVES YOU MONEY

*Diamond Service Engineer needs only a screwdriver to change the steam blowing pressure of an individual G98 Blower after his inspection of tube surfaces indicated that a pressure increase will improve cleaning in that particular location.*



*Diamond Service Engineer instructs operator in use of the Diamond Selectromatic Control Panel . . . how simple it is to change from single blower selection to a completely automatic sequential program.*

The severe punishment that boiler cleaning equipment must take in the normal course of its operation emphasizes the importance of the unique Diamond Service Policy. Throughout the 36 years it has been in force, this Diamond Service Policy has made significant savings and important improvements in boiler cleaning for many users of Diamond Blowers.

Every installation of Diamond Blowers in stationary water tube boilers is regularly inspected and adjusted *(unsolicited and without charge)* by one of the many full-time Diamond Field Service Engineers working from strategic points throughout the country. On an inspection call, the Diamond Service Engineer sees to it that the blowers are in good repair and adjustment . . . instructs operators in their correct use and care . . . recommends blowing schedules for maximum economy. Often he will detect potential trouble before it becomes serious or costly. This preventive maintenance has been of great value to many operators.

Numerous users tell us that this unique Diamond Service Policy was as important as the superior design of Diamond Blowers in their decision to buy Diamond equipment.

**DIAMOND POWER SPECIALTY CORP.**

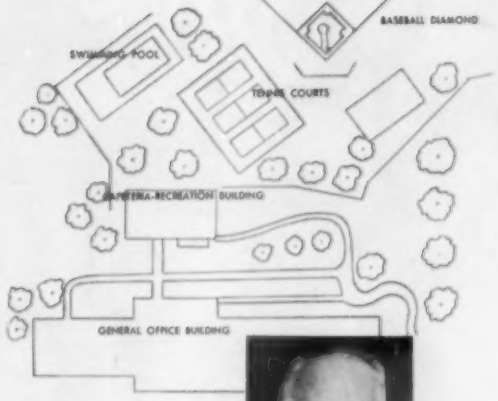
LANCASTER, OHIO

*Diamond Specialty Limited • Windsor, Ontario*

7065

# *a time to work and a time to play*

Shaw salutes Atlas Powder Company for their forward-looking philosophy which has resulted in handsome new offices for working time and modern recreational facilities for playing time. Located four miles from the center of Wilmington, Delaware, on a forty-five acre plot, the Atlas General Office Building is air- and sound-conditioned—designed for maximum efficiency and comfort. A walkway connects the General Office Building with a functional cafeteria-recreation building, where good food and good times go hand in hand. Outdoors is a large parking lot, a spacious swimming pool, tennis courts, a baseball diamond, and an attractive patio. Naturally, in planning the new offices and recreational facilities, the builders—The H. K. Ferguson Company—utilized the best obtainable materials—and the best possible workmanship. Small wonder, then,



Piping plays an extensive role in the new Atlas Building—for heating, air-conditioning, refrigeration, water and other services. We found the experience and resources of the Benjamin F. Shaw Company of major importance in completing satisfactorily—and on time—this vital phase of our project.

J. Charles Allen
*Chief Engineer, Atlas Powder Company*

that Shaw was chosen to fabricate and install the extensive piping for the air-conditioning, the heating, the swimming pool. Shaw's reputation for painstaking planning, skillful fabrication, and dependable installation is world-wide . . . and well-earned. Whatever your piping requirements, look to Shaw to fulfill them—carefully, reliably, economically.

BENJAMIN F. **SHAW** COMPANY

*Main Offices and Plant: Wilmington, Delaware* *Since 1893*